Weatherwise

Volume 10, Number 3 June 1957

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

Statement on Weather Modification

THE Council of the American Meteorological Society has assumed the responsibility for issuing periodic statements on the scientific aspects of weather modification and control. Two previous statements were issued in 1951 and 1953. In view of the additional information on this subject that has become available in the interim the Council deems it desirable to issue a revised statement of its opinion at this time. The statement on weather modification approved by the Society's Council at a meeting on 29 April 1957 is as follows:

1. The seeding of supercooled cloud with dry ice will usually convert at least a portion of the cloud to ice crystals. Under appropriate conditions such seeding may release variable amounts of precipitation from fairly deep and active cumulus clouds in which the natural release of precipitation has not already started. Small, inactive cumulus clouds are usually dissipated when they are seeded with dry ice. Holes or valleys may be produced in supercooled layer clouds or supercooled fogs by seeding them with dry ice.

2. The injection of water drops or hygroscopic salt particles into active, warm (non-supercooled) cumulus clouds may release some rain. Small, inactive, warm cumulus may often be partially or completely dissipated by seeding them from above with water drops or other particles; such dissipation may occasionally be accompanied by the release of very light rain.

3. In some cases warm fog and stratus may be dissipated in restricted regions by the use of certain hygroscopic materials.

4. At temperatures below about $-5°$ C, silver iodide crystals are known to affect supercooled clouds in much the same way as

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Front Cover: Hon. Harry S. Truman studies his daily weather map in his office with prominent AMS members:—Left to right: Ex-president Howard T. Orville, President Robert D. Fletcher, Executive Secretary Kenneth C. Spengler, and Edward Jacobson of the Kansas City Local Branch. Note current issues of *Congressional Record* and *Weatherwise* on Mr. Truman's desk.

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Weatherman Truman Greets the AMS

Thank you very much, Mr. Jacobson, for that most cordial introduction. I am very happy to welcome these good weathermen to the largest suburb of my home town of Independence.

You know, I have been interested in weather nearly all my life, at least since 1906, when I went back to the farm. My father and my good old grandmother, who lived to be 91 years old, were always interested in the weather. We followed a number of almanacs, and we watched the birds and the beasts and the family "rheumatiz" and generally could come close to whether it would rain or storm in summer and winter.

When I was in the second grade in the Independence Ward School, I had a lovely school teacher who said that she could tell when a weather change was coming by the way the youngsters squirmed around!

We had an old weatherman here in Kansas City by the name of Pat Connor, who was not only an efficient weatherman but also an Irish humorist. He told a good story on himself that I remember particularly. It seems he went to a picnic over in Clay County, across the river here, and had made a weather report that there would be rain that day. He met another weatherman, a farmer and an amateur in meteorological matters, who had told his friends to go ahead with the picnic, that it would be a fair day. Mr. Connor asked him on what information he based his prophecy. The farmer, who didn't know who Pat was, said, "Well, I just look at what Pat Connor says about the weather, and I know that if I say the opposite, I'll hit it." There are many stories along that line, and you just have to grin and bear them.

You have done a wonderful work in assembling all the data on general weather conditions. You helped to fix the date of the landing in France; you made it possible to pick the right day for the operations at Hiroshima and Nagasaki that ended the war with Japan and saved a quarter of a million youngsters from death on our side and the same number on the Japanese side.

I am most happy that you are working on this great storm area. There is no other place in the world like the area from the mouth of the Mackenzie River in Canada to the mouth of old Missip in the Gulf of Mexico. The clipper ship captains understood typhoons in the western Pacific and hurricanes in the Caribbean; they had to to survive. Washington and Jefferson kept weather records for farm use.

I am sure that your work in this great tornado area will do us a real service. I have seen the temperature drop 55° in less than three hours, and it is no trick at all for it to drop from 70° to zero in a day or two.

In 1906 my father, brother, and I were running a six hundred acre farm about seventeen miles south of where I am standing now. It is no longer a farm, but I have seen it rain in a field a half mile away with the sun shining on me plowing corn. How I prayed for that rain to hit my field so I could go to the barn! Sometimes it did, and my father would put me to work mending harness or swinging a scythe on the weeds in the fence corners.

Plantings and harvestings are vital to farmers who raise our food and livestock. This area between the Rockies and the Appalachians can cook up more different kinds of weather in less time than any other area in the world, with the possible exception of the western Pacific Ocean. I have always been interested in air currents and what causes our sudden temperature changes. I receive the national weather map by air mail from Washington every morning. The first things I look at in the morning are the newspaper's weather report and the weather map.

I hope that you will have a very successful meeting in my big suburb, and I hope that all of you will take a look at my Library, which will belong to you—the government of the United States. I expect to have a sun dial out there, a windvane, thermometers, barometers—a complete amateur weather bureau.

Good luck to you all!

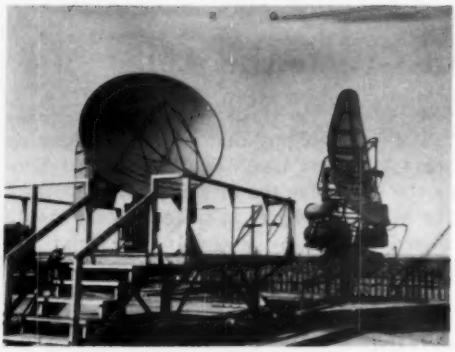


FIG. 1. Antennas of AN/CPS-9 and AN/TPS-10A Radars.

Radar as a Meteorological Instrument

PAULINE M. AUSTIN,
Massachusetts Institute of Technology

WHEN microwave radar was developed during World War II for the purpose of probing the atmosphere for aircraft, it soon became apparent that regions containing raindrops or snowflakes could also be detected and were presented as targets on the radar scopes. The appearance of these weather echoes suggested exciting possibilities for the use of radar as a tool for exploring the three-dimensional structure of storms which is on too small a scale to be properly described by the synoptic network. Soon after the end of the war, research projects were set up to examine the potentialities and liabilities of the radar as a meteorological instrument. Although its potentialities are not yet completely realized, the radar has provided data for significant contributions to research in both forecasting and precipitation physics, and its operational use has increased tremendously in the past few years. Both the U. S. Weather Bureau and the Air Weather Service maintain fairly extensive networks of weather radars; also, most of the major airlines are accepting airborne weather radars as necessary safety devices.

It is the purpose of this paper to give a brief description of the radar and a summary of its applications in meteorological research and operations.

DESCRIPTION OF THE RADAR

The radar sends out short, but very high-powered, bursts of microwave energy which are focused by a large antenna into a narrow beam only a few degrees in width. When the energy in the beam impinges upon an object, such as an airplane or a large number of raindrops, some of it is scattered or reflected from the object. The scattered energy travels in all directions and a small fraction of it comes back toward the radar and is received by the antenna as an echo. The direction in which the object causing the echo lies is indicated by the direction in which the antenna is pointing; the distance of the target is learned by measuring the length of time which elapses between the transmission of the pulse and the reception of the echo. Since microwaves travel at a fixed speed, the speed of light, the measured time is directly proportional to the distance of the target. Because light travels very rapidly, extremely short time intervals are involved in these operations. Several hundred pulses are sent out each second, each lasting about a millionth of a second. The time interval between the transmission of a pulse and the reception of an echo from a target 100 miles away is about one-thousandth of a second.

RADAR ECHOES FROM RAIN AND SNOW

The scale of radar observations, covering a distance of the order of a hundred miles with a resolution of the order of a mile, is very appropriate for the investigation of precipitation areas. Some typical patterns are shown in figures 2 and 3. The PPI (Plan Position Indicator) photographs show the precipitation in a plane swept out by the beam as the antenna rotates in azimuth. Because of the curvature of the earth the region viewed by the radar does not lie on the surface of the earth but becomes progressively higher as the range increases. The radar horizon at 100 miles is about 5000 ft. while at 200 miles it is 20,000 ft. The RHI (Range Height Indicator) photographs represent a vertical sec-

tion of the precipitation, taken at a fixed azimuth with the antenna scanning in elevation.

There are several questions which are frequently raised regarding weather radar observations:

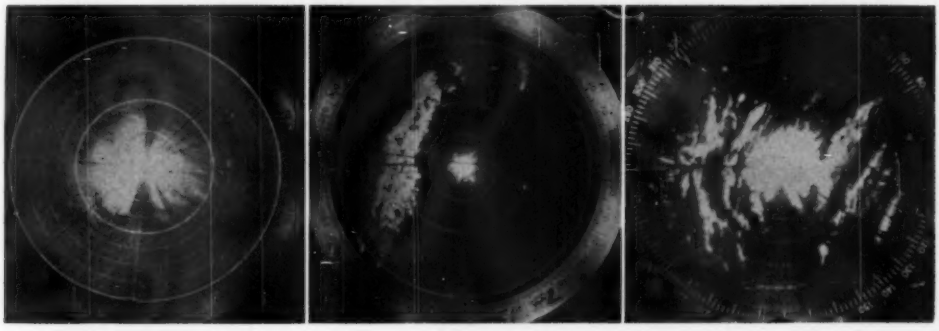
(1) How far away can radars detect rain?
(2) Can radars see clouds?
(3) Can a radar distinguish between rain, snow, sleet, hail, etc.?
(4) Can a radar measure the rainfall rate?

There is no simple clear-cut answer to any of these questions, but a consideration of the nature of echoes from precipitation provides some pertinent indications. Hydrometeors in the atmosphere are detectable if the echo received by the radar contains more energy than the random electronic disturbances within the radar system. In general, the energy in the echo from precipitation decreases rather rapidly as the range increases because the antenna intercepts a smaller fraction of the scattered energy. However, the limit of detection depends on many other factors also. The shorter the wave length the higher is the proportion of energy scattered by small particles, but the short wave lengths also suffer loss of energy through attenuation by rain and atmospheric gases. Wave lengths selected for weather radars range from 3 to 10 centimeters. Water scatters microwaves more efficiently than ice, and large particles scatter much more efficiently than small ones. Therefore, the radar sees rain to greater distances than snow, and heavy rain containing large drops is detected to greater ranges than light rain or drizzle. Cloud droplets are so small that they are not detected by most weather radars; special cloud radars use a very short wave length and point vertically so that only a few miles of range are required. A storm with deep vertical development can be seen farther away than low-level precipitation which may lie mostly below the radar horizon. In general, we may say that a high-powered weather radar can see moderately light snow to about 60 miles, and moderate rain to approximately 130 miles, while intense storms which extend well up into the atmosphere, such as severe thunderstorms or hurricanes, are often detected beyond 200 miles.

A radar cannot positively distinguish between different types of hydrometeors although there are qualitative differences in the appearance of echoes from rain and snow which serve as indirect indications to the experienced observer. When it is raining at the ground with snow aloft, the characteristic radar "bright band," a horizontal layer of enhanced radar reflectivity associated with melting snow (see fig. 3), usually marks the level separating the two types of hydrometeor. The radar can measure rainfall rate but not with a high degree of accuracy; its usefulness in this respect will be discussed more fully later.

Detection and Tracking of Severe Storms

Since precipitation is already in the vicinity of the station when observed on the radar

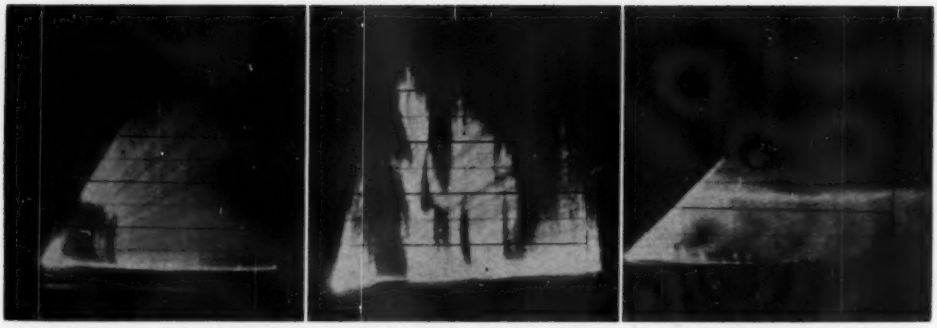


a. Uniform snow—200 mile range. (Dark wedges are shadows cast by nearby buildings.)

b. Large cold front band—100 mile range.

c. Bands of precipitation—120 mile range.

Fig. 2. Typical precipitation patterns on the PPI.



a. Uniform snow—50 mile range.

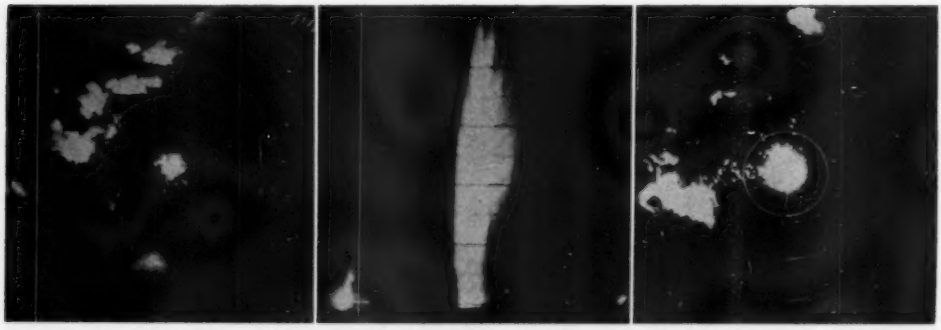
b. Large convective showers —50 mile range.

c. Radar "Bright Band"—25 mile range.

FIG. 3. Typical precipitation patterns on the RHI. Dark horizontal lines are at 10,000 ft. levels; the top of the scope is at 50,000 ft.

scopes, direct use of radar observations in forecasting, i.e., spotting the precipitation areas, watching their development, tracking them and extrapolating their behavior, is restricted to short range local forecasting. Its most valuable and dramatic use in this respect is in the detection and tracking of severe storms; this is probably the most important function of airborne radars. Often in the vicinity of thunderstorms and squall lines, clouds are numerous and widespread so that the pilot cannot tell by eye which areas contain relatively harmless clouds and which contain dangerous and turbulent storms. The radar easily detects the more intense portions of the storms, enabling the pilot to direct the plane around such areas. In figure 4a the radar shows a squall line containing intense thunderstorms with relatively open spaces between them. The intensity of the echoes, sharpness of the edges, and large size of the individual storms are all indications of severity. In addition, any irregularities in the shape of the storm such as protuberances or V-shaped notches are often associated with hail shafts or especially dangerous regions. A ground-based radar equipped with RHI can observe the height of the storm, a quantity which is highly correlated with both rain intensity and hail occurrence. Moreover, the rate at which a storm is building is a good indication of the degree of dangerous turbulence and possible development of damaging winds, hail, or tornadoes.

The potentialities of radar for the identification of tornadoes have aroused keen inter-



a. Squall line on PPI—120 mile range.

b. Vertical section of intense thunderstorm—50 mile range.

c. "Hook" associated with tornado at Worcester, Mass., 9 June 1953—40 mile range. Lincoln Laboratory photo.

FIG. 4. Radar photographs of severe storms.

est for several years. The association of hook-shaped or "6"-shaped echoes, such as that shown in figure 4c, with tornadoes is sufficiently well established so that emergence of one from the radar echo of an intense thunderstorm is considered sufficient cause for the operator to issue a tornado warning. However, there are also many cases when such hooks are not observed with tornadoes. Probably the most important contributions of the radar to the improvement of our tornado warning systems are its ability to detect and track especially intense storms which may be tornado breeders, and the provision of photographic records which permit the study of the structure and behavior of storms in which tornadoes have occurred. Composite pictures, which combine the echoes seen by a network of radars in the Midwest and are able to show the full extent and development of severe squall lines, are being studied to determine the situations where tornadoes are most likely to occur.

Hurricanes can usually be detected to great ranges and the spiral bands can be clearly recognized on the radar scopes. Techniques have been devised for locating and tracking the eye of the storm with a high degree of accuracy. Coverage of the Atlantic and Gulf coasts by radar is practically complete, and there are several installations in the Caribbean. Radar observations also provide many details of the internal structure of hurricanes, showing the differences between the convective showers in the outer bands and the more stable type of rain in the inner bands, as well as patterns of the spiral bands and circulation as revealed by the motion of the individual precipitation areas.

Local Forecasting

Most of the precipitation patterns revealed by the radar would be indicated on a synoptic map simply as part of a crosshatched area representing a general region of precipitation. Although observers at the surface are aware of the showery nature of most precipitation, and rain gauge records reveal the intensity and duration of the showers which happen to pass over them, the radar shows more details of the distribution of precipitation. The development and motion of precipitation can be studied by comparing photographs taken at short-time intervals. Surveys of radar data have shown that, in the average, convective showers are about 3 to 5 miles in both vertical and horizontal extent, and that they last about half-an-hour and their direction and speed of motion tend to correspond to that of the wind at the 700-mb level. This type of statistical information is very helpful to the meteorologist who wishes to make detailed local forecasts of precipitation since it establishes criteria for estimating the motion and duration of precipitation which is already occurring. Attempts are now being made to ex-

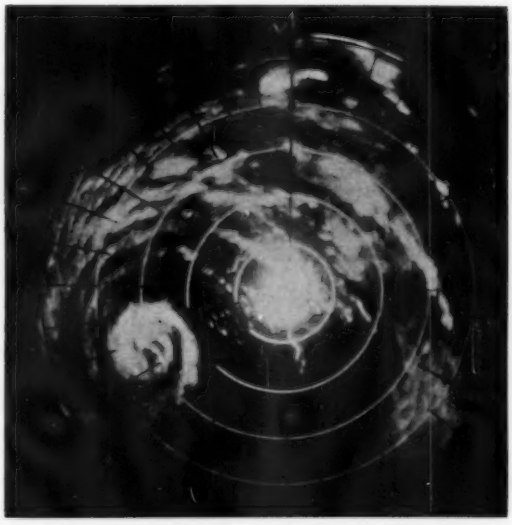


Fig. 5. Hurricane "Connie," 1955, as seen by radar at Cape Hatteras, North Carolina. 100 mile range. USWB photo.

plain the exact location of precipitation areas in terms of the local topography, surface wind field, and other synoptic parameters which are available to the forecaster; it is hoped that these studies will increase significantly the predictability of the distribution of precipitation.

Rainfall Amounts

The small scale variability of precipitation, which is clearly evident in radar scope data, makes one realize that only an extremely dense network of rain gauges can give an adequate description of the rainfall distribution. The detailed coverage provided by radars makes the possibility of measuring rainfall amounts by radar very attractive. There are two major difficulties involved in such measurements. The first is that there is no unique relation between the rainfall rate and the radar echo intensity. Rain containing relatively few large drops would produce a stronger echo than rain of the same intensity comprised of many small droplets. Empirical relations between rainfall rate and radar reflectivity have been established based on many observations of drop size distributions in natural rain. However, the accuracy of such relations is estimated at about a factor of two. Furthermore, the raindrops may be growing or evaporating so that the rain sampled by the radar, at or above the radar horizon, may not be representative of conditions at the ground.

The second difficulty concerns the measurement of radar signal intensity at all points over a large area. The radar echo from precipitation fluctuates rapidly in time because there are many scattering particles within the radar beam which are moving about with respect to each other and creating an interference effect between the waves scattered by different particles. Therefore, the measurement of the intensity of a weather echo involves averaging this fluctuating signal. Although the average need be taken only for a fraction of a second, the length of time required to cover a large area, point by point, becomes prohibitive. Devices for plotting signal intensity contours are available on some radars, however, and techniques for this type of measurement are being developed and improved.

There is no doubt that accurate measurements of radar signal intensity over an area will be extremely valuable for climatological records and flood warning as well as studies of the small-scale variability of precipitation. Already semi-quantitative techniques involving photographic integration of echoes on the PPI have shown promising results, and it is apparent that in many situations the advantages in coverage by the radar as compared with a network of rain gauges outweigh the uncertainties inherent in deducing rainfall rate from radar signal intensity.

Precipitation Physics and Storm Structure

Most of the physical principles involved in the initiation and development of precipitation particles have been well established by laboratory experiments, but it is difficult to watch these processes in the atmosphere. Spot observations of atmospheric conditions and hydrometeor types at different levels in the atmosphere can be made at mountain stations or by balloons or aircraft. The radar supplements such measurements by filling in the continuous small-scale pattern. Also, because of the sensitivity of the radar signal intensity to particle size and composition, measurements of the signal in different parts of the storm and at various levels help to identify the regions where snow crystals or raindrops are growing, aggregating, melting or evaporating, and give some information as to how rapidly these processes are taking place. Since much of our rain originates as snow aloft the investigation of the mechanisms of snow development and melting has received much attention in the field of precipitation physics. Radar has shown that in many cases, generally stratiform snow occurs in very small convective cells or "generating elements" which exist at a particular level as shown in figure 6. Sometimes snow trails are seen streaming behind convective cells as the flakes fall into regions of lower wind speed below the level of the cells. From the slopes of such trails it is possible to learn the fall velocity of the particles which in turn depends upon their size and structure.

Even the shapes of raindrops and snowflakes are being investigated by the use of circularly polarized radiation. The datum obtained is a measure of the departure from sphericity of the precipitation particles.

Measurements regarding the size and shape of particles in the "bright band" region are adding considerably to the understanding of aggregation and melting processes.

Turbulence and Wind Field

The rapid time fluctuations of signal intensity are an important characteristic of radar weather echoes. Analysis of these fluctuations tells about relative motions of the precipitation particles within the beam which are primarily caused by wind shear, turbulence, and differential fall velocities. Instrumentation for measuring signal fluctuations has been developed, but it is difficult to separate the effects of the various contributing factors and to assess their importance for different meteorological situations. Research efforts are being directed primarily toward examining the extent to which fluctuation data may be used to measure the turbulence in storms and exploring the possibility of detecting extremely high wind speeds such as those which occur in tornadoes.

Conclusion

The radar was first developed as a detection device, and its primary application as a weather instrument has been to detect precipitation regions and to show their extent, pattern, and motion. The great value of the radar lies in its ability to observe continuously in time and space on a scale which is eminently suitable to show details of storm structure which are important for local forecasting, including severe storm warning, and for studies of the physical processes involved in the development of precipitation.

Although high accuracy in the measurement of rainfall rate cannot be attained, the pronounced advantage in coverage enjoyed by the radar as compared with a network of rain gauges suggests that, with the improvement of techniques for measuring signal intensity over an area, radar will have important applications in hydrology and climatology. The study of small-scale atmospheric motions is another research problem to which radar contributes through analysis of weather echo fluctuations; the possibility of measuring turbulence and tornado winds by radar is being explored.

Acknowledgment

Except where otherwise noted, the radar scope photographs were taken on the AN/CPS-9 radar by Weather Radar Research, M.I.T., under the sponsorship of U. S. Army Signal Engineering Laboratories. The author wishes to thank Lincoln Laboratory, M.I.T., and the U. S. Weather Bureau for the photographs which they contributed.

References

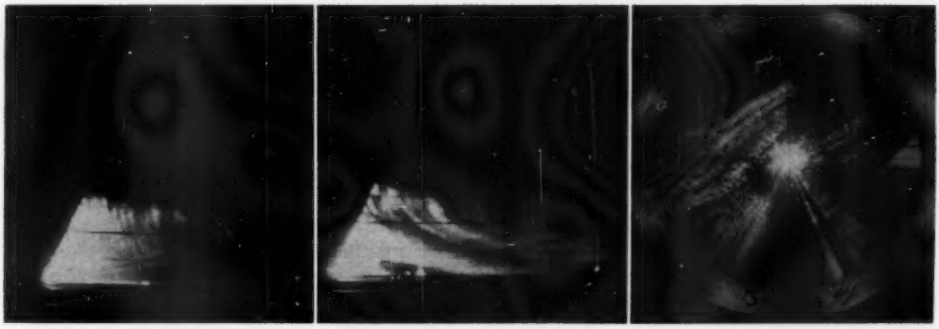
For an excellent bibliography of publications in weather radar, the reader is referred to:

Marshall, J. S., 1955: "Advances in Weather Radar," *Advances in Geophysics*, Vol. II, Academic Press, Inc., New York, N. Y., pages 1–56.

For more recent developments see:

Proceedings, 1956: Fifth Weather Radar Conference, September 15–19, 1955, Signal Corps Engineering Laboratories, Belmar, New Jersey.

Proceedings, 1957: Sixth Weather Radar Conference, March 26–28, 1957, Massachusetts Institute of Technology, Cambridge, Mass.



a. "Generating elements"—25 mile range.

b. Trails from small convective cells—25 mile range.

c. Small scale structure on PPI—50 mile range. (Dark wedges are shadows cast by nearby buildings.)

Fig. 6. Small-scale patterns in snow.

The Tornado Research Plane with instrumentation showing in cockpit behind pilot.

The Tornado Research Airplane

C. F. VAN THULLENAR, *Chief District Meteorologist, U. S. Weather Bureau, Kansas City, Mo.*

THE Tornado Research Airplane, owned and operated by Mr. Jim Cook under contract to the Weather Bureau, is an F-51. This airplane, instrumented primarily to measure the usual meteorological variables in the atmosphere—temperature, pressure, and humidity—was operated during the 1956 tornado season and is being operated again this season. The reason for using an airplane in research work on severe local storms has been somewhat obscured through an overemphasis on secondary objectives. Publicity in this regard has been too often to the effect that the intent is to investigate the tornado funnel. This, of course, is a spectacular objective, and hence, publicity has centered around this point. Actually, we are not too much concerned about this particular objective, and would not be concerned if no tornado funnel were seen from the plane. The primary objective in the use of the airplane was, and still is, to study the distribution of the meteorological elements associated with squall lines. The more spectacular objective involving whatever study is possible of the funnel cloud is incorporated in the flight objectives, but on the basis of accidentally having the airplane and the visible funnel in the same place at the same time. Placing the airplane and the tornado in the same place at the same time is very difficult and is not a primary objective.

An important part of the Air Weather Service and the Weather Bureau prediction programs is the forecasting of severe local storms. These storms are convective phenomena, usually associated with the squall line. We are all familiar with the appearance of a characteristic area which is referred to as the squall line on a synoptic chart. However, our understanding of such a line is, for the most part, confined to the weather which is occurring along or near the indicated line. There is not available a generally accepted concept of the vertical structure of the measured or derived meteorological elements that are associated with, and probably responsible for, the weather that is observed. Specifically, the question is whether the distortion of the measured or derived meteorological elements occurs before the weather or is a result of the weather.

Meteorologists have a fairly uniform idea of the vertical structure of the atmosphere through cold, warm, or occluded fronts in terms of measured or derived quantities.

This does not seem to be the case for squall lines. Since their occurrence must be forecast because of the relationship to severe local storms, it is obviously necessary to develop a better understanding of these phenomena.

The life history of the squall line is relatively short, usually measured in terms of hours. Many will argue, and with a good deal of logic in their argument, that the horizontal extent of the disturbed portion of the atmosphere, which is the squall line, is very small and nearly vertical. To date, certainly, we have not been able to establish definitely this structure from our upper-air network, even using 6-hourly upper-air observations on time sections. This would indicate a requirement for observations on a scale smaller in both space and time than our present upper-air network. Whether or not the airplane is the final answer for these observations may be debatable. However, there can be little doubt but that the airplane, even a single airplane, can furnish observations that will add to our knowledge of the structure of the squall line, as well as give us a better idea of what the final observational network must be. The use of a single airplane cannot give us a complete understanding, but it will go a long way toward giving us the knowledge required to plan an observational network, fixed or mobile, that will eventually pin down the structure of this very interesting and fast-developing phenomenon.

Instrumentation of the Tornado Research Airplane for the 1957 season includes the following equipment:

Vortex Thermometer (Naval Research Laboratory)
Platinum Resistance Thermometer (University of Chicago)
Infra-red Hygrometer (Weather Bureau)
Kollsman Recording Pressure Altimeter
NACA Velocity-Gust-Height Meter
16 mm Photopanel Camera
35 mm. Tracking Cameras
Voice Recorder
Dual OMNI (Visual Omni-Range Indicator)
10 cm Beacon (transponder)
Navy Aerograph (AN/AMQ-8)
Electric Field Meter
3 2-channel Brown Recorders

All cameras and recorders are tied together by a single, newly constructed, time synchronization system. In addition to the above, there will be a fixed-position movie camera, with a specially constructed wide-angle lens that can be triggered by the pilot, as well as an ordinary hand-held movie camera.

As stated above, the primary objective in the use of the Tornado Research Airplane is to study the formation of the squall line. We may approach a flight planning program by considering some generally accepted observations.

1. The phenomena with which we are dealing are associated with strong convection.

2. Strong convection, producing severe local storms, is often associated with squall lines.

3. Tornadoes are generally associated with severe local storms.

There are also available several hypotheses of squall line formation, a few of which are as follows:

1. Squall lines result from the cooling of air produced by evaporating precipitation. This may be the leading edge of a low-level convergence field. The idea here assumes that the precipitation occurs prior to the formation of the squall line.

2. A squall line is the leading edge of a gravity wave that moves downstream on an inversion surface at a speed greater than the environment.

3. The initiation of a squall line is an atmospheric action similar to the hydraulic jump.

4. Squall lines are a dynamic phenomenon that may form in dry air producing no weather or, at most, dust storms. They move in time and space producing severe weather in areas of sufficient moisture. For example, the squall line may be the result of a divergence-convergence couple acting over a relatively small horizontal cross section of the atmosphere.

If we think of these observations and hypotheses in terms of the distortion of meteorological elements in the vertical, it is found that a great deal of similarity results. For this purpose, and assuming dry air, consider a horizontal potential temperature (Θ) surface in a cross section, figure 1, which is the boundary between low level moisture and drier air above. In the region of convective

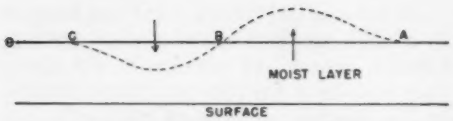


FIG. 1. Motion of potential temperature surface due to convective velocities under dry air conditions. The horizontal surface, ABC, transforms to the dashed line.

activity (A, B) the Θ surface must be displaced upward as indicated in the figure. The same type of displacement, because of the implied vertical motion upward, must result from 2, 3 and 4 of the summary hypotheses above. That portion of the Θ surface from B to C moving downward is required by the downward vertical velocity implied in 3 and 4 of the hypotheses above.

Since the lapse rate in the lower layers of the atmosphere in the warm seasons is nearly adiabatic, vertical motions result in little or no change of temperature. This would apply particularly to the section A-B of figure 1. However, a better indicator is available. The vertical motion upward will result in increasing moisture above A-B, and this is more easily measured. The vertical motion downward, often assumed to begin at high elevations in the region of the jet, will result in rising temperatures at all levels, as well as a drying-out process. Both are observable with a suitably instrumented airplane. Whenever dealing with the effects of vertical motion on temperature and moisture content it is, of course, necessary to subtract the effects of advection.

From these considerations it is possible to construct a fairly general schematic flight plan, figure 2. The severe local storms forecaster on duty gives the flight dispatcher a forecast of the position of expected squall line formation. We assume this to be the center point of the schematic of figure 2 and near B of figure 1.

No coordinates are indicated on figure 2 because there are likely to be considerable variations from case to case. However, in general, the upper portion of the flight plan will be near the 500-mb level and the lower portion from about 700 mb downward to the top of the moist layer. The two end points of the schematic flight plan indicate vertical soundings.

The airplane available can complete the closed path only on those occasions when the beginning point is within 30 minutes flying time from a base of operation and the horizontal extent is not much over 100 miles. It will then on any given occasion often be necessary to concentrate on only one portion of a total objective. It is highly desirable to fly the same level over the same line as often as possible before activity begins to determine the time rate of change of the meteorological elements.

Following the same schematic flight plan, figure 2, with an active squall line in existence, and the airplane located downwind from the squall line, vertical soundings and horizontal flights downstream will be used to measure changes occurring ahead of the line of activity. Conversely, should the airplane be positioned to the rear of an active squall line, the same type of flight planning will be used to measure changes in regions of post-squall line activity.

One of the more interesting observations of last season's operation was the extremely sharp horizontal moisture discontinuities in the atmosphere. Several records are available of a horizontal gradient in the dew point of over 10° C in not over four miles. These gradients occurred in one minute or less of flight travel. This season, when such sharp gradients are found, it is hoped to measure their slope by successive flights at various elevations through these discontinuities. This was done only once last season.

In the event the airplane is near an active tornado or an extremely bright radar echo, every effort will be made to take one or more vertical soundings in the vicinity and to

(*Continued on page 104*)

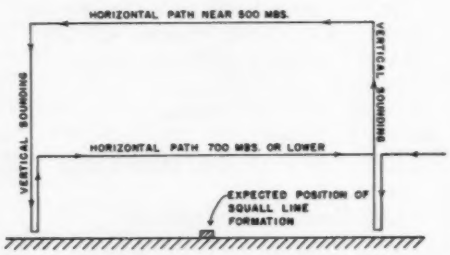

HORIZONTAL PATH NEAR 500 MBS.
VERTICAL SOUNDING
VERTICAL SOUNDING
HORIZONTAL PATH 700 MBS. OR LOWER
EXPECTED POSITION OF SQUALL LINE FORMATION

FIG. 2. Schematic flight plan for Tornado Research Plane.

This is the last of a series of six articles which have appeared in recent issues of *Weatherwise*. Each article discussed the prevailing tracks of highs and lows for two months.

Prevailing Tracks of Lows and Highs

WILLIAM H. KLEIN,
Extended Forecast Section,
U. S. Weather Bureau,
Washington, D. C.

GENERAL OBSERVATIONS

THE outstanding features of this series of articles can be generalized as follows:

1. Most cyclones, whether tropical or extratropical in origin, tend to have a northward component of motion. Anticyclones originating at high latitudes usually move southward, but in middle latitudes the predominant motion of anticyclones is from west to east.

2. Both cyclone and anticyclone tracks are generally farthest south in February, farthest north in August, and farther south in spring than fall. Northward displacement of the tracks is most rapid in late spring, southward displacement in late fall.

3. The spring season is characterized by frequent cyclonic activity at middle latitudes and minimum storminess at high latitudes, where blocking and anticyclonic circulations are frequent.

4. Cyclogenesis is most frequent to the lee of mountain ranges, over locally warm bodies of water, and on quasi-permanent frontal zones along the southeast coasts of continents.

5. Cyclones tend to travel over locally warm surfaces, anticyclones over locally cold surfaces. This effect is particularly striking over inland bodies of water, where there occur centers of maximum cyclone frequency in fall and winter and centers of maximum anticyclone frequency in spring and summer.

6. Mountainous areas are favored for anticyclones and anticyclogenesis, while cyclonic activity is frequent on the lee side of mountain ranges. Cyclones usually stay over flat surfaces and avoid mountainous terrain, while anticyclone tracks tend to curve anticyclonically on crossing mountains.

7. One of the most active meteorological areas of the world is the Great Basin of the United States, which leads the Northern Hemisphere in mean annual frequency of both cyclogenesis and anticyclogenesis.

8. On an overall basis, the Gulf of Alaska has the highest cyclone frequency of any portion of the Northern Hemisphere.

MAY CYCLONES

During the first four months of the year, the greater warmth of water surfaces relative to surrounding land was partly responsible for the existence of centers of maximum cyclone frequency over many inland bodies of water. During May, however, rapidly increasing insolation results in more rapid heating of land than adjacent water surfaces and even reverses the local temperature gradient in some regions. As a consequence, previously existing centers of maximum cyclone frequency either disappear or are displaced landward over the Great Lakes, Denmark Strait, Adriatic Sea, Black Sea, and Aral Sea; while new centers of minimum cyclone frequency appear in the western Mediterranean, Baltic Sea, English Channel, northern Bering Sea, and southeast coast of Newfoundland. At the same time, new centers of maximum cyclone frequency occur inland over such areas as Alaska, New Mexico, central Europe, and southern Scandinavia. In Siberia cyclones are more frequent during May than at any other time of year, and in East Asia a distinct center of low pressure is found on the normal sea level chart. Similar changes appear in the occurrence of cyclogenesis, which now becomes most frequent

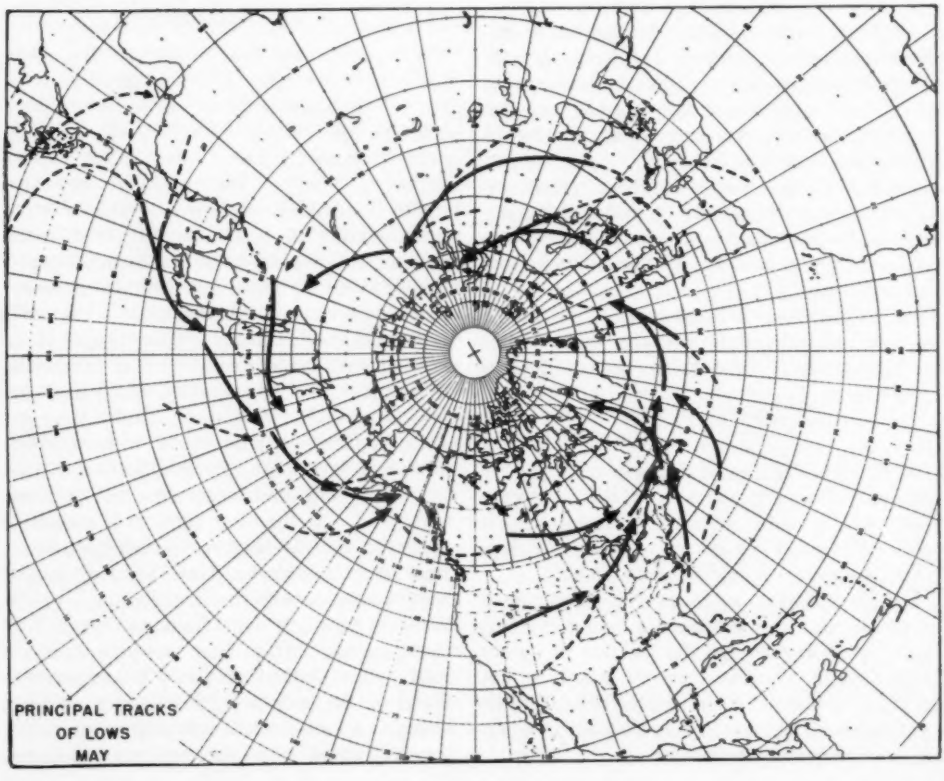
over inland areas such as the southern and central Plains, the Great Basin, Alberta, Manchuria, and the Alps.

These changes in the distribution of cyclone frequency and cyclogenesis are reflected in the principal storm tracks. In Europe cyclone paths which had been over water during the first four months of the year: i.e., in Mediterranean, Black, Caspian, and Baltic Seas, are displaced northward to land areas during May. The track over the Arctic Ocean north of the continent is reduced to secondary importance, while the one over southern Scandinavia becomes primary. The path across central Siberia now assumes primary status along its entire route. New secondary tracks emerge in Alaska and northwest Texas, while the course of Alberta lows shifts northward from the Great Lakes to Ontario. Finally, May marks the beginning of the active typhoon season in the Far East, where several secondary tracks are found in the vicinity of the Philippines.

May Anticyclones

The poleward shift of the principal anticyclone tracks which commenced in March

Principal tracks of cyclones and anticyclones at sea level. The prevailing direction of motion of systems is indicated by the arrows. Heavy solid lines denote primary tracks—those which are most frequent and generally indicated by various data sources; thin dashed lines denote secondary, less frequent, and less well defined tracks. All arrow heads end in areas where cyclone frequency is a local maximum. Here the tracks may cross, branch, and merge, although not specifically so drawn. Locally preferred regions of genesis are indicated where secondary or primary tracks begin, whether in centers of maximum cyclone frequency or elsewhere. An area of frequent genesis is also indicated when a single secondary track changes to a single primary track or when two secondary tracks merge to form a primary track, with a break between dashed and solid lines.

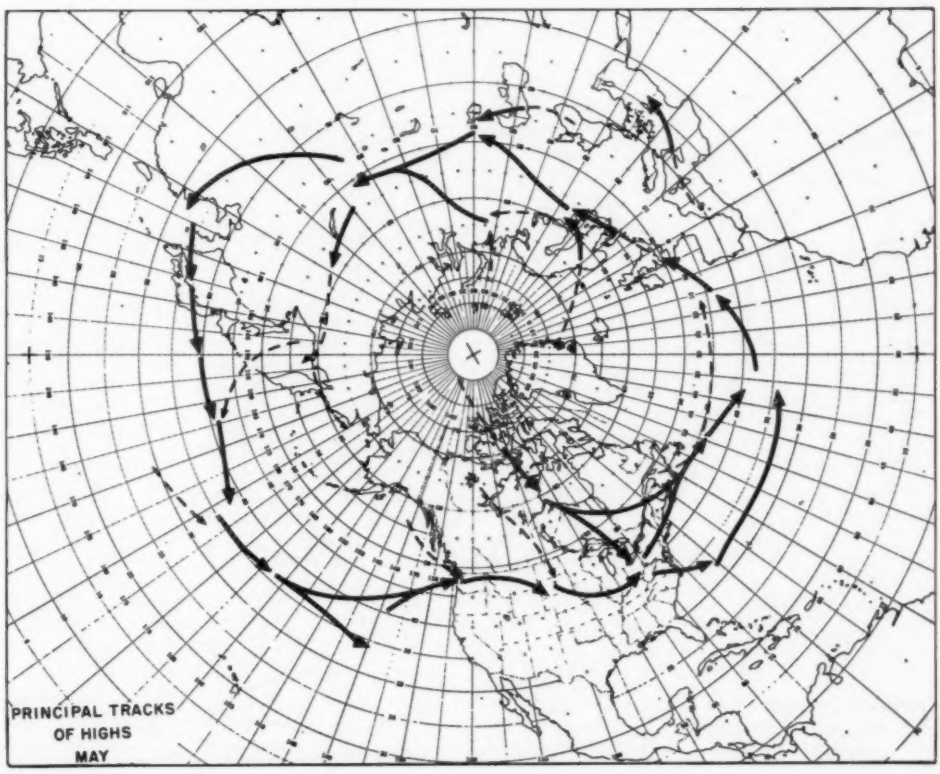


and April becomes more extensive during May. Not only does this northward displacement continue in the Pacific, western United States, Europe, and the Mediterranean, but it also occurs in Russia, Siberia, Korea, and along the southern Atlantic track. At low latitudes secondary anticyclone tracks disappear in the southern United States and in the Gibraltar area. Farther north, however, tracks through Pennsylvania, the Baltic, Lake Baikal, and the northern Urals, which were of only secondary importance during April, become of primary rank in May.

The land-water temperature contrast is responsible for continued increase in anticyclone frequency near the Great Lakes, Hudson Bay, and James Bay, where primary anticyclone tracks now appear. These changes, coupled with eastward shift of the tracks of arctic and polar highs, result in a higher frequency of anticyclones in central Canada than in western Canada, a phenomenon which is pronounced only during spring. Anticyclone frequency also increases over the cold waters of the Baltic Sea, Sea of Okhotsk, Bering Sea, and Gulf of Alaska. In the latter three areas local centers of maximum anticyclone frequency and secondary tracks are found in May. Anticyclogenesis becomes frequent over cold bodies of water, not only those listed above, but also in the Black Sea, Caspian Sea, English Channel, Yellow Sea, and Sea of Japan. In the Mediterranean the frequency of anticyclogenesis now exceeds that in any other area of the Northern Hemisphere.

June Cyclones

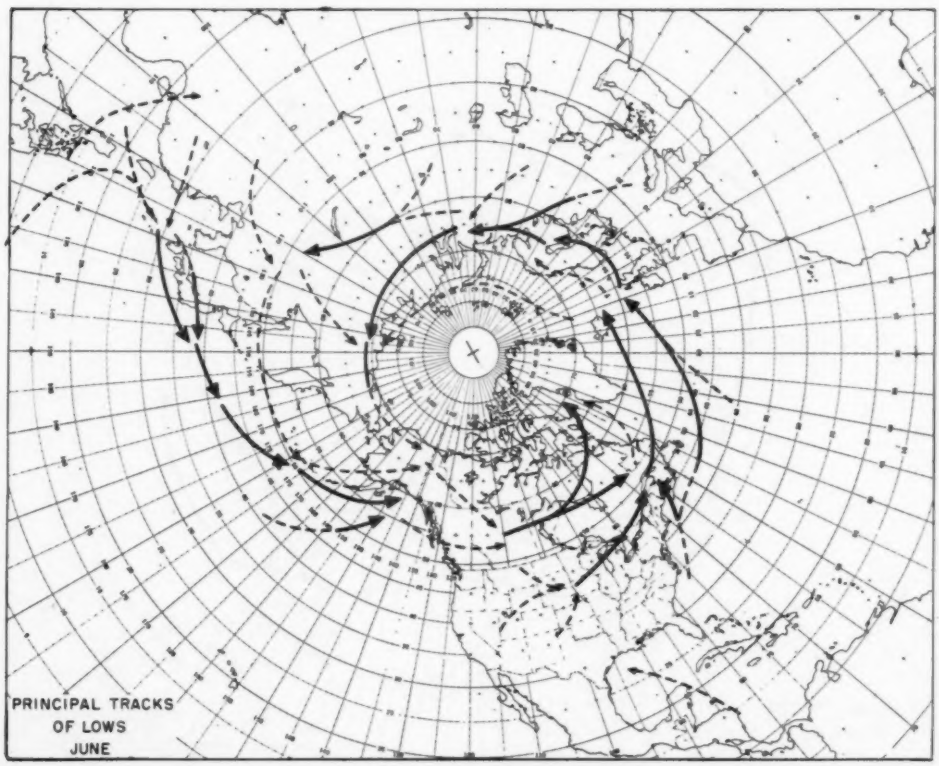
Although June is usually considered the first month of summer, it retains many of the characteristics of spring and even of winter in its cyclone distribution. For example, the primary track of extratropical cyclones from the Ryukyu Islands northeastward across the Pacific still passes east of Japan and just south of the Aleutian chain into a center of maximum cyclone frequency in the Gulf of



Alaska, in much the same way it does every month from January through May. Again in June a primary storm track passes northeastward across the Great Lakes, St. Lawrence Valley, and just north of Newfoundland, along a route virtually unchanged during the first six months of the year. As before, most of these storms originate in either the Great Basin or the Great Plains. Typical cyclone characteristics of spring which persist into June include: cyclogenesis in China, absence of a storm track in the Canadian Arctic, abundant activity in Siberia, double secondary track in western Canada, and diminished cyclone frequency over cold coastal waters just east of Greenland and Newfoundland.

On the other hand, many new and typical summer features appear during June including: a more zonal trajectory of cyclones in the eastern Atlantic, a storm track up the west coast of Japan, a split secondary track to either side of the Sea of Okhotsk, northward displacement of the track of Alberta lows (with primary importance attached to the branch through Hudson Bay), disappearance of the zonal track in southern Europe, and marked increase in cyclone frequency in the Canadian prairie provinces. In Alberta, the number of different lows exceeds that found anywhere else in the hemisphere, and June is the only month with a low pressure center on the normal maps. As a result, the center of action in the Davis Strait is now fed primarily by storms originating in western Canada, while the track from Labrador and Newfoundland is reduced to secondary status.

A few aspects of summer which made their initial appearance in May become more marked during June. These include: the presence of storm tracks and centers of maximum cyclone frequency in Alaska; and primary importance of the tracks over land across the northern part of Eurasia, in contrast with secondary rank of the tracks over the Arctic Ocean to the north. Typhoon ac-

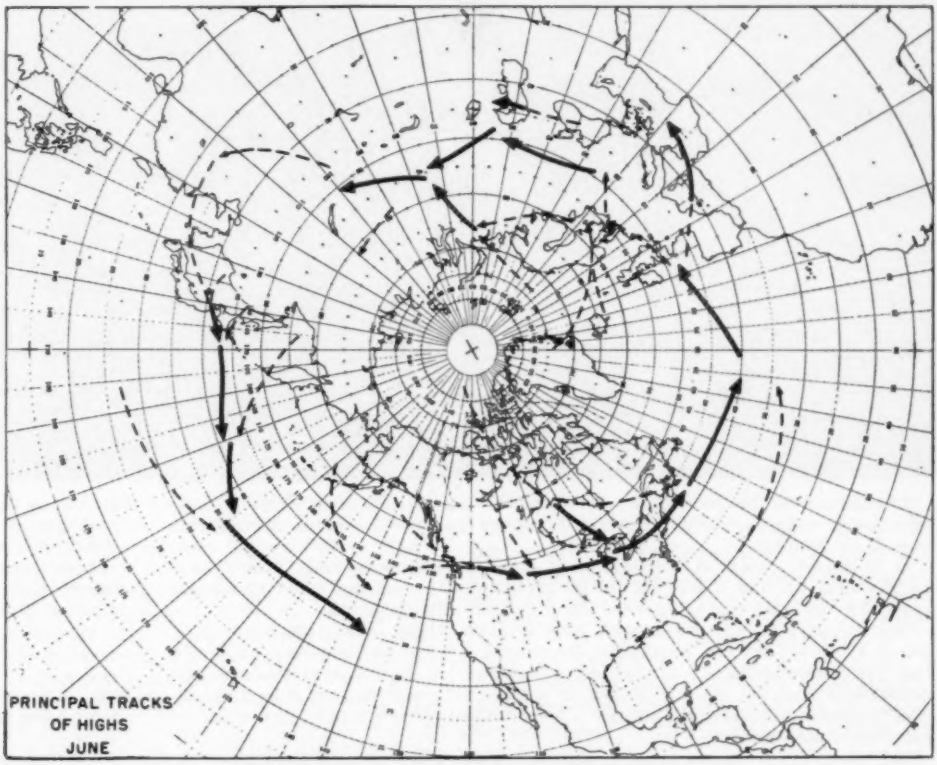


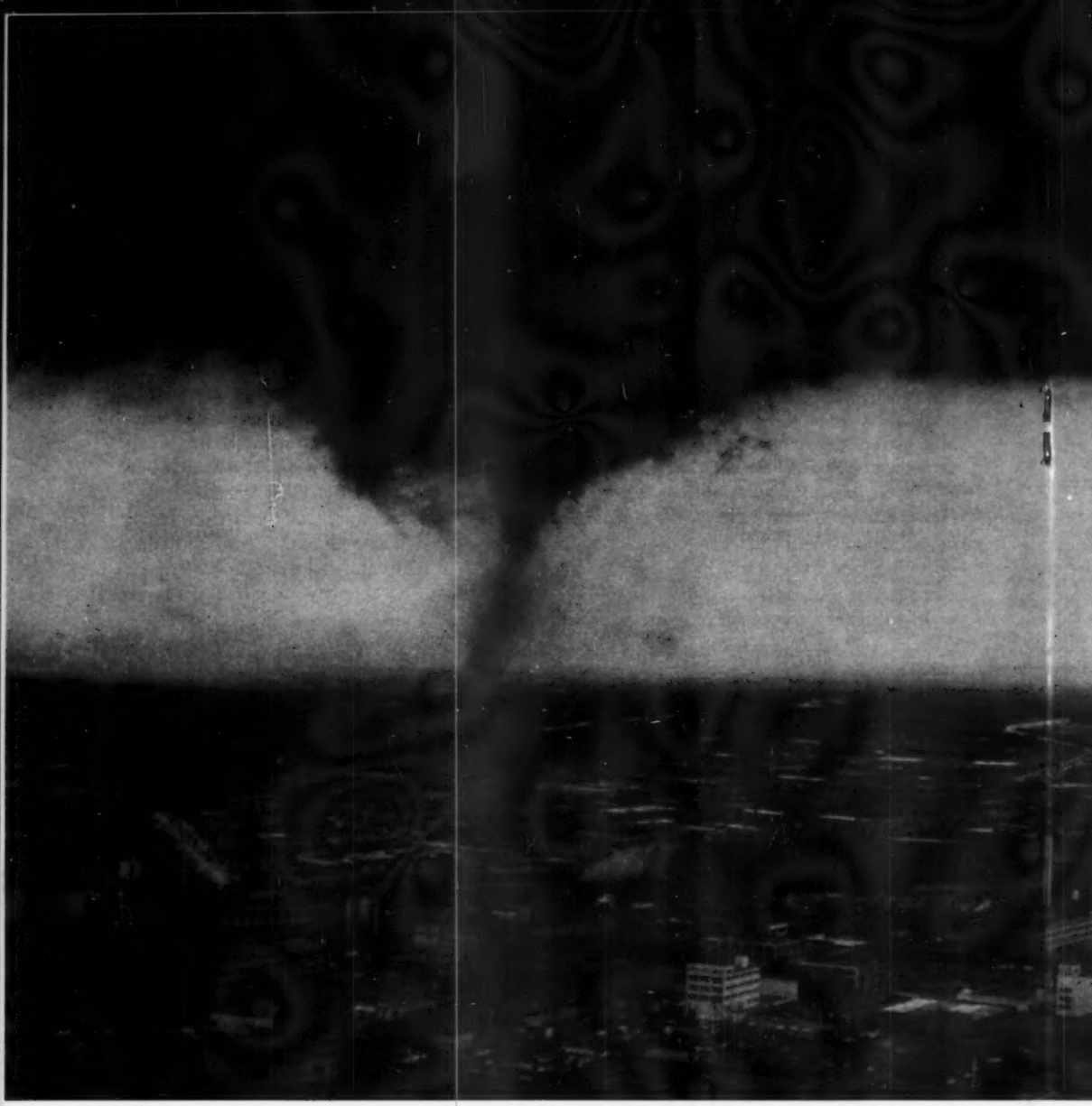
tivity now becomes more prominent, and some tropical depressions also appear in the Caribbean and the Gulf of Mexico.

June Anticyclones

General northward shift of the westerlies from May to June is accompanied by northward displacement of the anticyclone tracks in the United States, the Pacific, and Asia. At the same time the track in the Atlantic between 30° and 35°N is reduced from primary to secondary importance. As a result, a single primary anticyclone track now extends in a zonal direction across the United States and Atlantic around 45°N, in much the same fashion as it does all summer.

The frequency of polar outbreaks generally declines from May to June. This is indicated by reduction from primary to secondary status of anticyclone tracks through central Canada, eastern Asia, and southern Scandinavia. Likewise, secondary tracks of May in northwest Canada and northeast Siberia vanish by June. However, secondary paths of polar highs now originate over the cold waters south of Iceland and Spitsbergen and north of Canada, as well as in the Gulf of Alaska, Bering Sea, and Sea of Okhotsk. The cold water effect is also indicated by an increase of anticyclone frequency over the Mediterranean and the appearance of additional centers of maximum anticyclone frequency over Sable Island, the Black Sea, Caspian Sea, Barents Sea, Bay of Biscay, and Gulf of Finland. Another notable feature of June is the marked reduction in anticyclone frequency in eastern Asia, where the summer monsoon is responsible for disappearance of the former track around 60°N and conversion to secondary rank of routes across China, Korea, and Japan. Primary tracks are likewise diminished to secondary ones in Europe and the extreme eastern Pacific, where no strongly preferred paths are evident in June.





This photograph was taken from a penthouse atop the Republic Bank Bldg., the tallest building in Dallas. I was about 600 feet above the ground, with an unobstructed view in all directions.

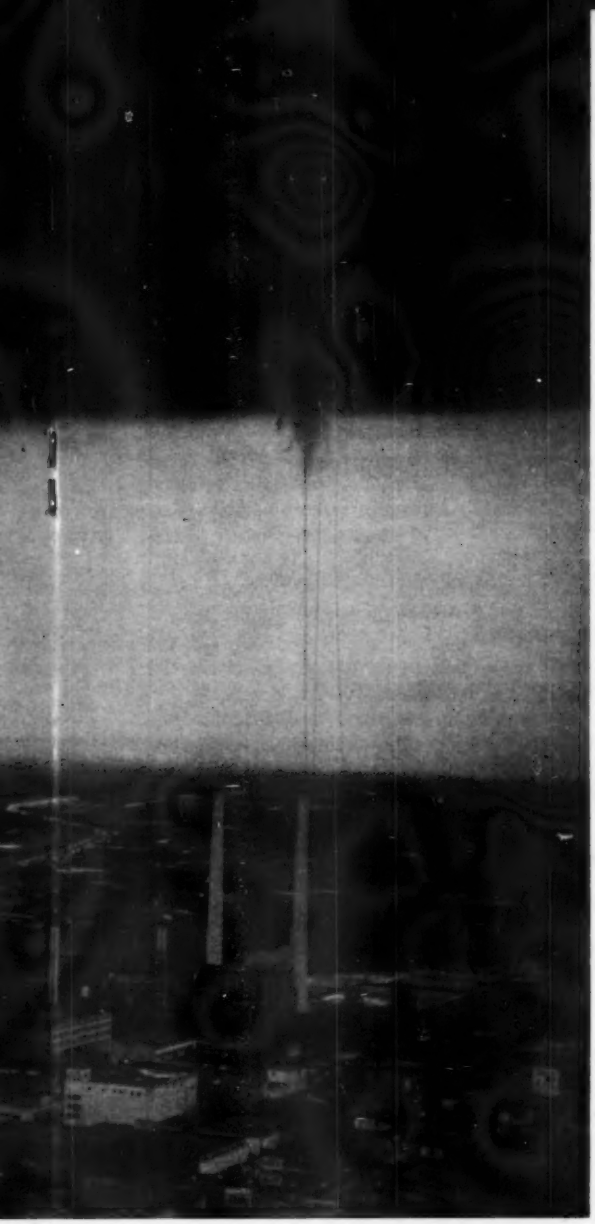
In all, I took a series of nine pictures, at about four-minute intervals, recording the tornado from the time it first touched the ground until it dissipated about 40 minutes later. The camera I used was a 4 × 5 Speed Graphic with Tri-X film.

The first picture I took was the one with downtown Dallas in the foreground. This was at 4:31 p.m., and the tornado had just touched down in the southwest part of the Oak Cliff section of Dallas. At that point, the funnel was moving in an almost-perfect northeasterly direction—directly toward the camera and the downtown area of Dallas. Shortly after, the funnel's path assumed a more northerly direction and passed about 1½ miles from downtown.

The second funnel began forming at about 4:50 p.m.—about 1¼ miles northeast of the primary funnel. At that time, base cloud was about 1,50[illegible] feet distinctly defined, the bottom of feet, or about ¼ of the distance moved along, ahead of and slig ing after about four or five mi

The primary funnel stayed o back up into the parent cloud. few minutes of its life, the fun like, seeming to lag behind the being "out-run" by the parent

CLIFF POPE, *Regional Pub*



t that time, I would estimate that the bottom of the second funnel's
ut 1,500 feet above the ground. As the secondary funnel became more
he bottom of the secondary funnel extended downward about 500–600
the distance from the bottom of the base cloud to the ground. It
of and slightly to the east of the primary funnel. It began dissipat-
r or five minutes, and within 10 minutes, had completely dissipated.
nel stayed on the ground for about 15 minutes more before pulling
arent cloud. You might be interested in knowing that for the last
life, the funnel cloud became progressively narrower and more rope-
behind the forward progress of the parent cloud, almost as if it were
the parent cloud.

Regional Public Relations Representative, American Airlines, Dallas.

Dallas Tornado

2 April 1957

MALCOLM C. HARRISON, *MIC,*
U. S. Weather Bureau,
Love Field, Dallas

A series of thunderstorms in north central Texas spawned numerous tornadoes on the late afternoon of 2 April 1957, one of the first being the tornado which originated in southwest Dallas and moved northward across the western sections of the city. The tornado, with a forward speed of approximately 25 mph, cut a more or less continuous path about 300 to 400 ft. in width and approximately 16 miles in length from the southwest outskirts of the city to just west of Love Field Airport in northwest Dallas. The tornado at first was moving almost due north, but after travelling over about half of its path, veered slightly to the north-northwest.

The tornado passed about one mile southwest of the Weather Bureau quarters in the Love Field Terminal Building, and while no noise was heard at this point originating from the tornado, there were numerous reports of loud roaring accompanying the tornado from witnesses nearer the storm. The barometric pressure dropped .04 inch at the Weather Bureau, with the lowest pressure being 29.10 inches at station elevation and 29.61 inches corrected to sea level. Time of the lowest pressure was 4:48 p.m. The tornado was preceded by intense, but brief, rain and light hail. Total rainfall was .40 inch at the Weather Bureau, with .36 inch in 5 minutes. A momentary gust of 63 mph was observed at the Weather Bureau Office during the rainstorm and preceding the passages of the tornado at its nearest point to the office. The tornado was trailing from the rear edge of a large cumulonimbus cloud system. A definite rotation of the funnel was observable in a counter-clockwise manner, with structures exploding when struck and large debris being carried aloft several hundred feet before falling to the ground.

This was perhaps the most documented (both observed and photographed) tornado on record and the low number of casualties was a miracle.

CLIMATOLOGY

OF

THE UNITED STATES,

AND OF THE

TEMPERATE LATITUDES OF THE NORTH AMERICAN CONTINENT.

EMBRACING A FULL COMPARISON OF THESE WITH

THE CLIMATOLOGY OF THE TEMPERATE LATITUDES OF EUROPE AND ASIA.

AND ESPECIALLY IN REGARD TO

AGRICULTURE, SANITARY INVESTIGATIONS, AND ENGINEERING.

WITH

Isothermal and Rain Charts

FOR EACH SEASON, THE EXTREME MONTHS, AND THE YEAR.

INCLUDING A

SUMMARY OF THE STATISTICS OF METEOROLOGICAL OBSERVATIONS IN THE UNITED STATES, CONDENSED FROM RECENT SCIENTIFIC AND OFFICIAL PUBLICATIONS.

BY

LORIN BLODGET,

AUTHOR OF SEVERAL RECENT REPORTS ON AMERICAN CLIMATOLOGY; MEMBER OF THE NATIONAL INSTITUTE AND OF VARIOUS LEARNED SOCIETIES.

"When the varied inflections of the Isothermal Lines shall be traced from accurate observations in European Russia and Siberia, and prolonged to the western coast of North America, the Science of Distribution of Heat on the Surface of the Globe will rest on solid foundations."—HUMBOLDT'S *Address before the Imperial Academy of St. Petersburg*, 1828.

PHILADELPHIA:
J. B. LIPPINCOTT AND CO.
TRÜBNER AND CO.; LONDON.
1857.

The Father of American Climatology

JAMES K. MCGUIRE, *U. S. Weather Bureau, New York, N. Y.*

JULY 1957 marks the one hundredth anniversary of the publication of the first major study of the climates of the United States. The book was entitled (in part) *Climatology of the United States and of the temperate latitudes of the North American continent* [1], and its 536 pages were the work of Lorin Blodget. Both book and author deserve to be recalled, since there is more than ordinary historical interest attached to these almost forgotten names.

Lorin Blodget was born in Jamestown, N. Y., on 25 May 1823, and educated at the academy in that town and at Hobart College, Geneva, New York. Cleveland Abbe, himself a leading pioneer in American meteorology, stated that Blodget's interest in weather and climate "was aroused during the years 1841–1844 when traversing Wisconsin, Illinois and Iowa for the purpose of examining and purchasing land" [2]. Since Abbe knew Blodget, this account may be considered reliable. It is very likely confirmed by Blodget's subsequent development; as Ward [3] has remarked, "Blodget stands out as preeminently a *practical* climatologist"; he was far more interested in the application of his science to human affairs than in its theoretical aspects.

Nevertheless, much was being done and said about the weather during the first half of the nineteenth century by American educational, scientific, and governmental agencies, in addition to many private individuals [4, 5]. As a young college graduate, Blodget must have been aware of this "learned" activity and some phase of it may also have influenced him toward climatology. At any rate, he became a cooperative observer in the network which the Smithsonian Institution established in 1849. He thus came to the attention of Joseph Henry, the first Secretary of the Smithsonian, who was a central figure in the development of American meteorology. The Smithsonian was collecting local and state-wide weather records, past and current, for an investigation of the dynamic features of cyclonic storms; Henry employed Blodget from 1851 to 1854 in "the reduction of the meteorological records that were rapidly accumulating." This employment was terminated, to continue Abbe's account, "owing to a difference of opinion as to his right to use these official records for his own publications" [2]. Blodget next found employment in the Medical Department of the U. S. Army. By order of the Surgeon-General in July 1818, a series of weather observations had been started at each Army post [6]; these records had been published through 1842. Blodget had a major share in the preparation of the *Army Meteorological Register* for the years 1843–1854 [7]. In the Letter of Transmittal which prefaced the volume, Assistant Surgeon-General Coolidge wrote as follows:

> The general arrangement of the tables, and the grouping of the stations in climatological districts, were adopted principally at the suggestion of Lorin Blodget, Esq., who has been associated with me in the preparation of the entire work. The isothermal and rain charts were designed and prepared exclusively by him, and he is entitled to whatever of scientific value may attach to them, and to the accompanying report explanatory of the principles upon which they were constructed, and of the results which they exhibit.

The report referred to in the foregoing consists of an eighty-two page study of (in Blodget's words) "the prominent features of general climate in the United States, as exhibited in the distribution of temperature and of rain, and in explanation of the illustrative charts." The report was used, practically verbatim, in the *Climatology* that appeared two years later; the isothermal and isohyetal maps were also reproduced with small changes. Thus, the *Army Meteorological Register* served as a dress rehearsal for Blodget's principal production. In both works, he shows himself as an indefatigable and intelligent worker, with the ability to handle large masses of data, extract the significant points, and present them clearly and accurately. With good reason, then, Blodget asserted in the preface of his *Climatology* that "no part of the present work, whether supported by statistics and illustrations or not, is the result of hasty or superficial discussion, and . . . all the steps

of analytical investigation and detailed criticism required for such a purpose as that of constructing an approximate climatology, have been taken in advance." The book was his *magnum opus,* and after its publication his main attention turned to other than climatological concerns. Settling in Philadelphia, where "for a long time he was general appraiser of customs" [2], he also engaged in journalism, and wrote voluminously on financial and business topics. Blodget never entirely abandoned his interest in weather, however, for he was active in the Pennsylvania State Weather Service and wrote on the climatological records of that State. He died, aged seventy-seven, on 24 March 1901.

Forty-odd years after its publication, Cleveland Abbe referred to Blodget's *Climatology* as "a book that attracted much attention and is still often quoted, although its different sections are of very unequal value" [2]. The reason for this long survival, aside from any intrinsic merits, may well be due to the fact that no comparable work appeared until almost a quarter-century after Blodget's death. The U. S. Weather Bureau issued numerous collections of climatological data, and several descriptions of local and regional climates were published, but Blodget had no rival as the author of a nation-wide climatography until Robert DeCourcy Ward brought out *The Climates of the United States* [8] in 1925.

In his preface, Ward stated justly: "While many of Blodget's generalizations still hold true, his discussion, as well as the data upon which it is based, is from our present point of view incomplete and unsatisfactory." On the other hand, Blodget's *Climatology* had positive values which Ward handsomely acknowledged ten years earlier. In an "Appreciation" of Blodget's book in the *Monthly Weather Review* in 1913, Ward wrote:

> During the short semi-vacation of the past summer, spent among the New Hampshire hills, I have turned again to Blodget's *Climatology of the United States* for relaxation and for instruction. More than ever before, I am impressed by the labor involved in the preparation of this book; by the author's broad and clear view of his subject; and by the practical application of the facts. My rereading of this book has given me new light on my path as a teacher. . . .
>
> It was no easy task which Lorin Blodget set for himself. It would have discouraged many men. But Lorin Blodget did it. And he did it well. . . . Out of the confused mass of scattering observations which had been accumulating from distant sources at the Smithsonian Institution and the Office of the Surgeon-General, and from "gentlemen at distant points distributed over the country," Blodget brought order and accuracy so far as was then possible [3].

The rest of Ward's four-page article is a series of comments, mainly favorable, on specific points in Blodget's book.

The importance of this work to the present generation lies in the fact that the need which Blodget sought to fill still exists today. In its turn, Ward's *Climates of the United States* has become outmoded: not that it does not contain much of lasting value, but because it naturally lacks the increased climatological knowledge accumulated over the thirty years that have elapsed since its publication. The 1941 Yearbook of the U. S. Department of Agriculture, entitled *Climate and Man,* contains a wealth of data in chart and tabular form on the climates of the United States, as well as "Supplementary Climatic Notes" on each State prepared by Weather Bureau climatologists. This publication serves many of today's requirements for climatological information about our nation, and ranks with Blodget and Ward as a landmark in American climatology. Yet, the future will undoubtedly bring forth a successor to these volumes; and it will almost surely, like *Climate and Man,* be the product of several authors or at least based on the work of many people. So vast is the information now accumulated, so many and varied are the industrial, business, agricultural, and other applications of climatology, that no one man—not even a Blodget or a Ward—can now hope to write, singlehandedly, a comprehensive climatography of the United States. Such a work will, however, trace its parentage back to 1857 and to the first effort of an almost-forgotten pioneer.

References

1. Blodget, Lorin: *Climatology of the United States, and of the temperate latitudes of the North American continent. Embracing a full comparison of these with the climatology of the temperate latitudes of Europe and Asia. And especially in regard to agriculture, sanitary investigations, and engineering. With isothermal and rain charts for each season, the extreme months, and the year. Including a summary of the statistics of meteorological observations in the United States, condensed from recent scientific and official publications.* Philadelphia, J. B. Lippincott and Co.; London, Trübner and Co., 1857.

(Continued on page 97)

Books for the Amateur Meteorologist During IGY 1957-58—II

MALCOLM RIGBY, *Editor:*
Meteorological Abstracts and Bibliography

IN the April *Weatherwise* an attempt was made to review some of the large and growing number of books and publications which might prove interesting and informative to the nonprofessional meteorologist (using the broad definition of meteorology employed by Aristotle: the science of the earth, the sea, and the atmosphere and anything that enters the earth's atmosphere). Only ten such publications could be covered in the available space, and in the following pages only a few more are mentioned of the dozens that might be included.

SOLAR INFLUENCES (cont.)

Three other books which give technical information on the sun and the causes of auroral, ionospheric, radio, and magnetic disturbances, as well as on the general aspects of the physics of the earth's atmosphere and surface, are: **The Sun and its Influence: an introduction to the study of solar-terrestrial relations** by M. A. Ellison of the Royal Observ., Edinburgh. Macmillan Company, New York, 1956. 235 p., figs., plates. $4.50. It deals with the sun, its radiation, activity such as sunspots, solar flares, faculae, corona, etc., the ionosphere, aurora, radio waves from the sun, cosmic rays, effects on the earth's magnetic field and on radio, but with little about the effects on weather. Another famous astrophysicist, Gerald P. Kuiper of the Yerkes Observatory, has edited two collections of articles by outstanding scientists entitled: **The Sun**, Chicago, Univ. of Chicago Press, 1953. 745 p., numerous figs. and photos. $12.50; and **The Earth as a Planet**, Univ. of Chicago Press, 1954. 751 p., photos. $12.50. The first "compendium" covers the entire range of subjects in the field of astrophysics mentioned in the book by Ellison and includes the measurement of the solar constant, the zodiacal light, eclipse effects on the ionosphere, rocket observations of the ultraviolet light from the sun. The second "compendium" contains 15 articles by well known meteorologists or astronomers such as H. R. Byers, H. U. Sverdrup, Fred Whipple, D. R. Bates and others, on subjects such as physical oceanography, the "lower" atmosphere (up to 30 km.), the biochemistry of the atmosphere, the earth as seen from a satellite, the albedo and color of the earth as seen from a rocket.

The practical aspects of solar research, giving some insight into the purpose of all of this coordinated study of the sun and the outer atmosphere, is covered in **Solar Energy Research,** edited by Farrington Daniels and J. A. Duffie, Univ. of Wisconsin Press, Madison, Wis., 1955. 290 p., 53 figs. $4.00. This is a compendium of articles on every aspect of solar energy availability and use: expected demands for energy, quality and amount available, effect of atmosphere and meteorological elements, space heating and domestic uses, solar power, evaporation and distillation, conversion to electrical power, conversion in nature to wind and other forms of energy, conversion by plants and in the sea, solar furnaces, chemical and photosynthetic uses, etc., etc. Along the same lines is **Generation of Electricity by Wind Power,** by E. W. Golding, London, Spon, Ltd., 1956. 318 p. $12.00.

HYDROMETEOROLOGY AND OCEANOGRAPHY

Besides the sun, the upper atmosphere, ionosphere, aurora, cosmic rays and meteors, two of the most important fields to be studied in the IGY during 1957–58 concern the waters of the earth, and come under the disciplines of glaciology and oceanography. Many of the aspects of hydrology which relate to these interesting fields of study are covered in **Realms of Water: some aspects of its cycle in nature,** by P. H. Kuenen of the Univ. of Groningen, Netherlands. Translated by May Hollander. New York, John Wiley, 1955. 327 p., 190 figs., 16 plates. $6.50.

This is a popular scientific book dealing with water in all of its manifestations in nature, originally published in Dutch in 1948, but just recently made available to the English reading audience. It takes up the hydrologic cycle, water in the ocean: waves, breakers, tides, currents; evaporation, clouds, rain; water in the ground: springs, caves, artesian water; surface waters: lakes, waterfalls, rivers, erosion; water in the solid state: snow, snow cover, avalanches, glaciers, ice-ages, and a host of other aspects which appeal to the imaginative mind.

Several other books come to mind for brief mention.

All About the Sea by Ferdinand C. Lane. Illustrated by Fritz Kredel. New York, Random House, 1953. 148 p. $1.95, deals with life in the sea, geological and physical processes going on in the deep sea, as well as the surface features such as waves, tides, currents, salinity, control of climate and weather by the sea, origin of the seas, and other subjects of interest to the teacher or layman.

Mariner's Meteorology by C. G. Halpine and H. H. Taylor. Van Nostrand, Princeton, 1956. 371 p., illustr., maps. $8.00, is a textbook of high quality for naval officers and others interested in marine aspects of the atmospheric behavior with special emphasis given to forecasting and observing at sea. Hurricanes, the jet stream, radioactive fallout from tests of nuclear weapons, and other modern aspects of meteorology are treated.

The Sun, the Sea, and Tomorrow: potential sources of food, energy, and minerals from the sea by F. G. Smith and Henry Chapin. Scribner, New York, 1954. 210 p. $3.50. This work investigates solar power obtainable from sea plants, land plants, water power, heat pumps, wind power, heat from the sea, tidal power, and many other forms of power or food that may be in common use in 100 years when our supplies of oil and coal dwindle.

Meteorology for Mariners, with a section on Oceanography. Air Ministry, Meteorological Office. Publ. by H.M.S.O., London, 1956. 274 p., 107 figs. $2.80, is an excellent and practical handbook or textbook for students or seamen. Every one of the 26 concise chapters is slanted toward the marine aspects of meteorology, climatology, forecasting, etc. Chapters cover cyclones and hurricanes, forecasting, ocean currents, ice and its forecasting, the physics, chemistry, geology, optics, biology and meteorology of the oceans, oceanographic cruises and their functions. Instruments and observations at sea are not emphasized since these constitute a companion text to **The Marine Observer's Handbook**, also published by the Air Ministry, Met. Office.

The Wind and the Weather by Joe Bolton. Crowell, New York, 1957. 277 p. $3.95, is a chatty book by a weather broadcaster, covering a host of subjects connected with post-war weather service: the IGY and satellites, atomic explosions and the weather, hurricane reconnaissance, tornado research, cycles, military meteorology, instances where weather made history, effect of weather on man, sunspots, weather control, old-fashioned winters, blizzards, floods, and what have you?

Synoptic and Dynamic Meteorology

For the amateur who wants to "beat the experts" in some particular specialized field of meteorology (and the fact that a man is an amateur does not mean that he is not equipped mentally or educationally to handle as difficult material as the man who earns his living in a given field), there are a number of fine, though expensive, books which have been published in the last year or two. Some of these are really bargains at the price quoted. Most notable among these is **Dynamic Meteorology and Weather Forecasting** by C. L. Godske, T. Bergeron, J. Bjerknes, and R. C. Bundgaard. Published jointly by the American Meteorological Society and the Carnegie Institution of Washington, Waverly Press, Baltimore. 800 pp., illustr. $15. This monumental volume (almost as big as the **Compendium of Meteorology** published by the American Meteorological Society in 1951) is a complete revision and completion of the classical "Physical Hydrodynamics" of V. Bjerknes, the father of the Norwegian School of Meteorology. The present elegant edition was actually compiled in consultation with V. Bjerknes, and was completed in 1948 as a memorial to the latter by four of his closest collaborators. Although publication difficulties prevented it from appearing for almost a decade after completion, most of its content

is as valid as if it were written today, for it covers all of the basic concepts of thermodynamics and statistics of the atmosphere, kinematics, hydrodynamics of the general circulation, wave motion, turbulence, climatology on a global basis, cyclones and anticyclones, fronts, atmospheric tides, effects of mountain ranges, synoptic analysis (surface and upper-air), and forecasting using the concepts of the world-famous Bergeron. It will be recalled that Bergeron insists that observations and weather maps should actually *depict the weather* and not merely show lines of purely mathematical significance. He also maintains that most professional meteorologists are not professional, but deal with an unreal and limited mathematical approximation of the atmosphere, and not with the weather itself.

Climatology

(*Continued from page 94*)

2. Abbe, Cleveland: Obituary Notice of Lorin Blodget, *Monthly Weather Review,* Vol. 29, No. 4 (April 1901), U. S. Weather Bureau, Washington, D. C., p. 174.
3. Ward, Robert DeCourcy: "Lorin Blodget's 'Climatology of the United States': An Appreciation," *Monthly Weather Review,* Vol. 42, No. 1 (January 1914), U. S. Weather Bureau, Washington, D. C., pp. 23–27.
4. Miller, Eric R.: "American Pioneers in Meteorology," *Monthly Weather Review,* Vol. 61, No. 7 (July 1933), U. S. Weather Bureau, Washington, D. C., pp. 190–193.
5. Abbe, Cleveland: "A Chronological Outline of the History of Meteorology in the United States of North America," *Monthly Weather Review,* Vol. 37, Nos. 3–6 (March–June, 1909), U. S. Weather Bureau, Washington, D. C., pp. 87–89, 146–149, 178–180, 252–253.
6. Smart, Charles: "The connection of the Army Medical Department with the development of meteorology in the United States," in U. S. Weather Bureau Bulletin 11, Part 2 (1895), Washington, D. C., pp. 207–216.
7. U. S. Army: *Army Meteorological Register, for twelve years, from 1843 to 1854, inclusive, compiled from observations made by the officers of the Medical Department of the Army, at the Military Posts of the United States,* Public Printer, Washington, D. C., 1855.
8. Ward, Robert DeCourcy: *The Climates of the United States,* Boston, Ginn and Co., 1925.

Southland Weather Handbook. John H. Aldrich and Myra Meadows. The Weather Press. Box 45452, Airport Station. Los Angeles 45, Calif. 1956. 48 p. $1.50.

California weather is the most talked-of weather known to man, the authors tell us—"and much of what is said about it is true, in some sections of the state, at some season of the year. California astounds both her residents and guests with the hottest, driest, dampest, foggiest, sunniest—even the snowiest—weather in the United States."

This large-format 48-page publication concerns itself with the California area south of the Santa Cruz and Yosemite latitude. Since it is, to the reviewer's knowledge, the first attempt of recent vintage to present a popular survey of the climate and weather of a particular region, a listing of the chapter headings will give the reader a concise idea of the book's scope: The role of topography, Where our weather comes from, The weather forecast, Terminology, Weather by months, Smog; humidity and comfort, To the private pilot, Weather modification, The home barometer and other instruments. There is also a useful appendix containing wind and temperature scales, sunrise-sunset data, long-term means of all elements for Los Angeles, the L. A. Airport, Burbank, and San Diego, and a schedule of weather information available over local radio and television.

Obviously, the organization of this handbook must have given many headaches to the authors, who are employed in the Weather Bureau forecast center at Los Angeles. They seem to have solved it well, and packed a great deal of information into a small space. They have made use of graphs and charts wherever possible. The reviewer especially likes the series of 12 full-page monthly charts depicting temperature and precipitation data for each month. These also contain smaller insets showing data for the immediate Los Angeles County area in detail.

Weather handbooks or guides of similar scope should be produced for all sections of our vast country. As James McGuire points out elsewhere in this issue, publications on the American climate have been extremely scarce. It is high time that there was less talk and more real writing about the weather of our country, so that we may pass on to the general public the mass of information that is now locked up in the meteorological brains of our profession.

Southland Weather Handbook should prove extremely useful to anyone who either lives in or intends to visit California. It is hoped that it will find its way into the schools and be used as a supplement to the regular geographical texts. In fact, anyone interested in following the ways of American weather will find much of interest and instruction here.

D. M. L.

Weatherwatch

MARCH

A Turbulent Spring Season

DAVID M. LUDLUM, *Editor*

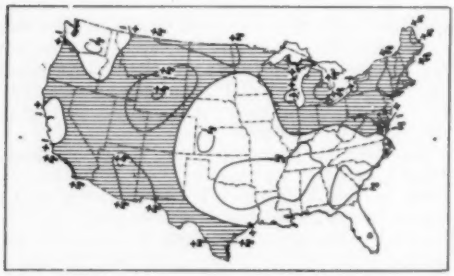
The early spring of 1957 will long be remembered both in the pages of weather annals and in the columns of the public press. In addition to an almost daily succession of news-making meteorological events, certain climatic trends appeared that seem to have reversed long-continued anomalies which had come to be accepted as almost normal. These occurrences stood in direct contrast to the winter season of 1956–57 which was relatively placid except for the unusually severe cold weather in the North during mid-January. But March and April witnessed a parade of blizzards and cloudbursts, floods and droughts, freezes and record warm spells, along with an unprecedented crop of destructive tornadoes over a wide geographic spread—all seemingly in much greater profusion and severity than is the usual spring fare. Most of the activity took place over the southern Great Plains with Texas, in particular, witnessing an atmospheric battle of the weather elements which seemingly has turned the tide in that area's long struggle with devastating drought.

MARCH—The weather maps of March were marked by two centers of cyclonic activity which produced important meteorological effects across the entire nation. The area of the North Pacific Ocean directly south of Alaska either developed new storm centers or reinforced old ones, in direct contrast to the lack of stormy conditions there during January and most of February when ridge conditions prevailed. Though the actual low centers were seldom able to break through the double barrier presented by the coastal mountains and the atmospheric ridge over western Canada, a number of fronts detached themselves from the main storm systems and swept southeastward, bringing fresh impulses of polar maritime air onto the continent to make a very wet time of it in the Northwest states. Measurable rain or snow fell in either Oregon or Washington on every day of the month from the 1st to the 26th of March. It was the wettest March in almost 50 years of record at Medford, Oregon, and Yakima, Washington.

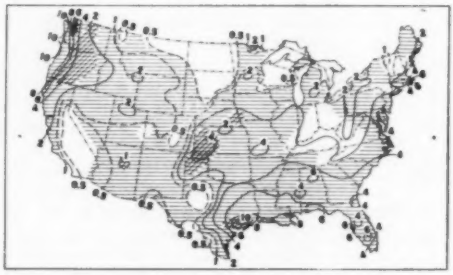
The prevailing air flow in the West in March was from west-northwest to east-southeast, and the area of maximum westerly flow was much further south than normal. Thus, the jet stream was found at 34° N (northern Texas) rather than at its normal minimal position at 38° (central Kansas). This fast air stream ushered all fronts which entered the Pacific Coast southeastward to the southern Plains where, encouraged by trough conditions existing there, new centers formed with active circulations, pulling moist Gulf air northward to overrun the polar air from the Pacific or Canada which followed the fronts. Thus, an ideal precipitation situation was established for copious rains over the southern Plains and the lower Mississippi Valley, the first time since 1952 that such a situation persisted for more than a few days.

The charts depicting pressure departures from normal readily show the reasons behind the air mass movements which made March a wet month. At the general steering level of 10,000 ft., the pressure height contours over the United States were every-

MONTH OF MARCH 1957



Departure of Average Temperature from Normal in degrees Fahrenheit. USWB chart.



Total Precipitation in inches. USWB chart.

where below normal, while to the north over Canada and adjacent water areas pressure heights were well above normal for the season. A general western ridge-central trough-eastern ridge pressure system existed across central North America. The dominating feature of the entire chart was a blocking high over Labrador and adjacent Davis Strait west of Greenland. This block was instrumental in producing a low index type of westerly flow with much north-south transport of air masses, the usual creator of spectacular weather events.

A study of cyclone tracks of the month reveals that the western ridge was able to repel the attempted entry of low centers from the Pacific Ocean with the single exception of that of 12 March which later developed into Blizzard No. 1. Several of the low centers were held stationary off the coast for many hours, all the while producing heavy rains eastward over Oregon and Washington.

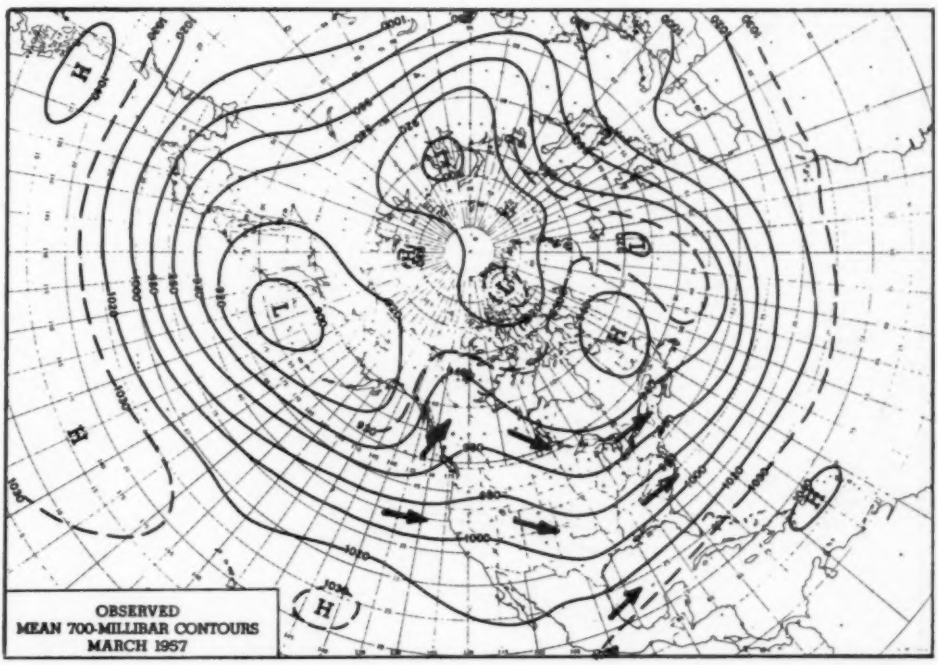
The blocking high in northeastern Canada also shunted low centers from their usual course. The principal storm path east of the Mississippi River, rather than following the normal St. Lawrence Valley track, moved eastward from the area of cyclogenesis in the southern Plains or the west Gulf, across the Southeastern states, and into the Atlantic Ocean generally south of Virginia, accounting for the belt of heavy precipitation along the Gulf and in the southern Appalachians.

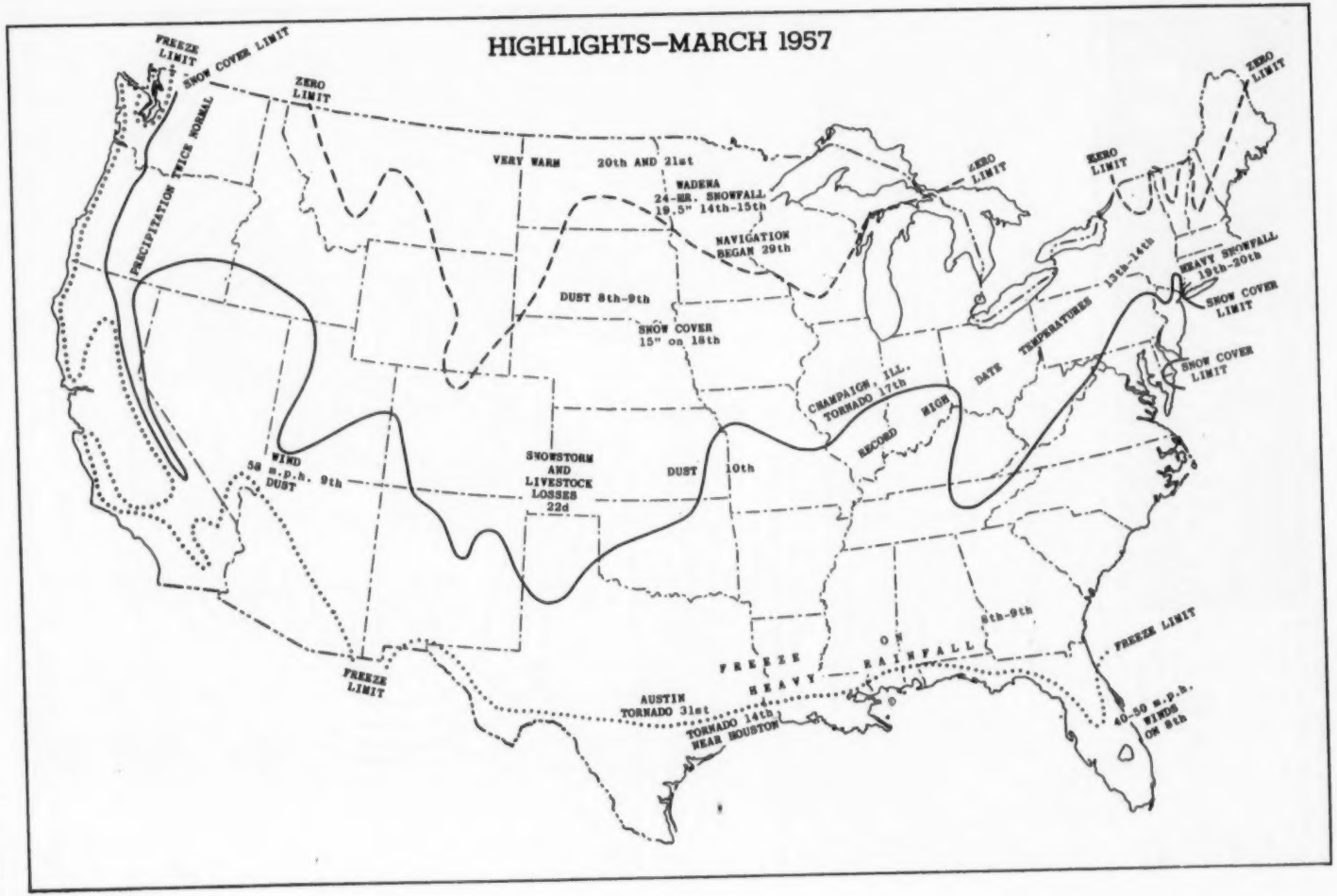
The effect of the blocking high in the Northeast showed up in areas of deficient precipitation along the northern border. With the jet stream over southern United States, moist air streams from the Gulf of Mexico could not penetrate north of 35° N except for a few days at the middle of the month when Blizzard No. 1 was controlling the circulation. Most depressions shunned the Lakes area and the Northeast, and sped directly eastward to join the cyclonic vortex in the mid-Atlantic Ocean. Droughty conditions persisted in March in the wheat country of the northern Plains. And it was a very dry month in the Upper Ohio Valley and through New York State and New England where the precipitation deficiencies of March contributed to a widespread fire hazard in April.

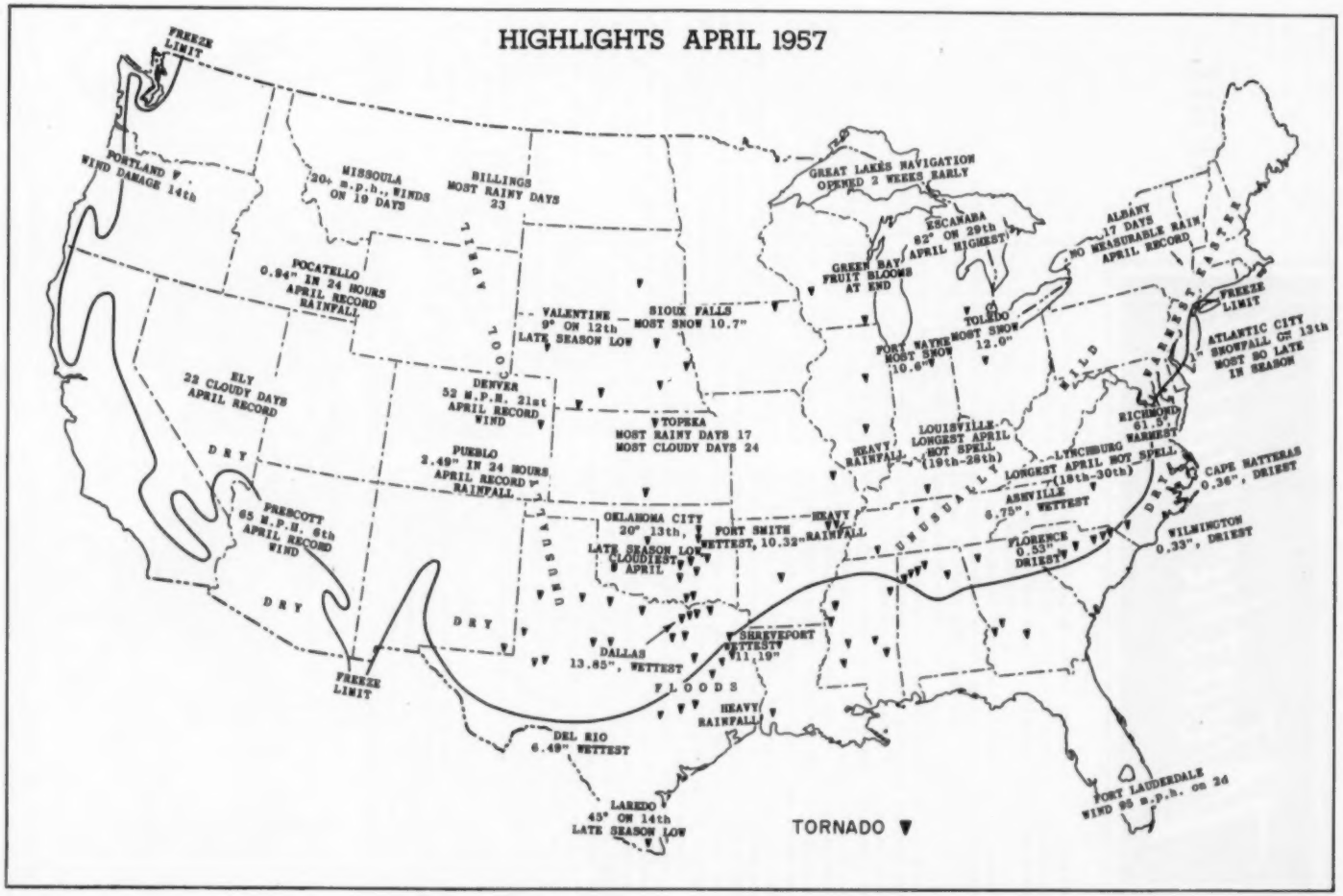
There were two spectacular snowstorms during March that gripped the attention of the entire nation as outstanding news stories. Both reached maturity in the Great Plains and may be classified, especially in their western and northern quadrants, as warm blizzards or as spring blizzards, for all the characteristics of a true winter blizzard were present except for the absence of near-zero temperatures in the heart of the storm. Blizzard No. 1's progenitor moved inland from the Pacific Ocean across Oregon on 12 March and looped southeastward across Wyoming and Colorado where it set off very heavy mountain snows. In the lee of the Rockies the center regenerated on the 13th. Temperatures in Kansas and Nebraska on the afternoon of the 12th were

(*Continued on page 106*)

The upper-air map below shows the pattern of air flow for January at about 10,000 feet, on which the average weather largely depends. The contours lines represent the mean height of the 700 mb. pressure level. Figures are in tens of feet: 1020 = 10,200 ft., 980 = 9,800 ft., etc. USWB chart.




HIGHLIGHTS–MARCH 1957
FREEZE LIMIT
SNOW COVER LIMIT
ZERO LIMIT
PRECIPITATION TWICE NORMAL
VERY WARM 20th AND 21st
WADENA 24-HR. SNOWFALL 19.5" 14th-15th
NAVIGATION BEGAN 29th
DUST 8th-9th
SNOW COVER 15" on 18th
HEAVY SNOWFALL 19th-20th
TEMPERATURES 13th-14th
DATE
RECORD HIGH
CHAMPAIGN, ILL. TORNADO 17th
WIND 58 m.p.h. 9th DUST
SNOWSTORM AND LIVESTOCK LOSSES 22d
DUST 10th
FREEZE
HEAVY RAINFALL ON 8th-9th
AUSTIN TORNADO 31st
TORNADO 14th NEAR HOUSTON
40-50 m.p.h. WINDS ON 8th


HIGHLIGHTS APRIL 1957
FREEZE LIMIT
PORTLAND
WIND DAMAGE 14th
MISSOULA
20+ m.p.h., WINDS
ON 19 DAYS
BILLINGS
MOST RAINY DAYS
23
POCATELLO
0.94" IN 24 HOURS
APRIL RECORD
RAINFALL
ELY
22 CLOUDY DAYS
APRIL RECORD
DENVER
52 M.P.H. 21st
APRIL RECORD
WIND
VALENTINE
9° ON 12th
LATE SEASON LOW
SIOUX FALLS
MOST SNOW 10.7"
TOPEKA
MOST RAINY DAYS 17
MOST CLOUDY DAYS 24
PUEBLO
2.49" IN 24 HOURS
APRIL RECORD
RAINFALL
PRESCOTT
65 M.P.H. 6th
APRIL RECORD
WIND
OKLAHOMA CITY
20° 13th,
LATE SEASON LOW
CLOUDIEST
APRIL
FORT SMITH
WETTEST, 10.32"
RAINFALL
DALLAS
13.85", WETTEST
SHREVEPORT
WETTEST
11.19"
FREEZE LIMIT
DEL RIO
6.49" WETTEST
LAREDO
43° ON 14th
LATE SEASON LOW
GREAT LAKES NAVIGATION
OPENED 2 WEEKS EARLY
ESCANABA
82° ON 29th
APRIL HIGHEST
GREEN BAY
FRUIT BLOOMS
AT END
FORT WAYNE
MOST SNOW
10.6"
TOLEDO
MOST SNOW
12.0"
ALBANY
17 DAYS
NO MEASURABLE RAIN
APRIL RECORD
FREEZE LIMIT
ATLANTIC CITY
SNOWFALL ON 13th
MOST SO LATE
IN SEASON
RICHMOND
61.5°
WARMEST
LOUISVILLE
LONGEST APRIL
HOT SPELL
(19th-26th)
HEAVY
RAINFALL
LYNCHBURG
LONGEST APRIL HOT SPELL
(18th-30th)
ASHEVILLE
6.75", WETTEST
FLORENCE
0.53"
DRIEST
CAPE HATTERAS
0.36", DRIEST
WILMINGTON
0.33", DRIEST
HEAVY
RAINFALL
FLOODS
HEAVY
RAINFALL
FORT LAUDERDALE
WIND 55 m.p.h. on 24
DRY
DRY
DRY
DRY
UNUSUAL
UNUSUAL
TORNADO

Weatherwatch

APRIL

APRIL—As the spring season moved from March into April, the pressure systems across North America continued their tendency to shift westward and at the same time the strength of the troughs and ridges diminished somewhat in intensity. The mean upper-air map for April exhibited a more conventional pattern for the season. The influential blocking high of March over Labrador and Davis Strait moved westward, first into the Hudson Bay region, and eventually joined forces with the ridge which had persisted since winter over either Alaska or western Canada. By mid-April a marked low pressure trough, stretching from the pole to the mid-Atlantic, occupied the erstwhile retreat of the blocking anticyclone. The magnitude of this readjustment is revealed by the reversal in mean sea level pressures for the region off the southwest Greenland coast: from a plus 11 mb departure in March to a minus 9 mb reading in April. The removal of the block in the Northeast, of course, had important repercussions on the movement of highs and lows all over the continent.

Changes of lesser magnitude took place in other portions of the Northern Hemisphere as the elements sought to readjust to a more normal spring pattern. A high index of westerly flow now prevailed across the continent, and the position of the jet stream moved considerably northward. Centers of cyclonic activity were in the expected places: the Aleutian Islands area in the North Pacific and off southern Greenland. From the latter a trough trailed southward to the central North Atlantic Ocean where it was a stormy month for trans-Atlantic sea and air passengers.

Over the United States, in contrast to March conditions, there were now two general pressure compartments, arranged longitudinally, with the Mississippi River serving as the approximate boundary. To the east, barometric readings averaged above normal as a stronger than usual tropical high took up a position over the West Indies and Florida, somewhat reminiscent of summer conditions. In the western half of the United States, pressure continued below normal with the largest minus departure located in Utah. The desert area of the Southwest was the habitat of a persistent trough most of the month, a condition which permitted frequent cyclogenesis in the Mexican border region with a resultant storm track across the plains of Texas.

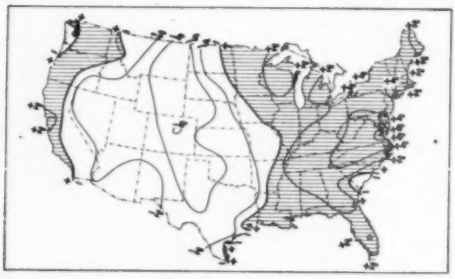
The pressure pattern in western North America was complicated by the presence of a ridge over western Canada directly north of the trough over the American Southwest. The presence of a polar ridge directly north of a low-latitude trough is not an unusual situation for western North America, and usually has important effects on the distribution of precipitation across the United States.

The air flow of the month was generally from the west-northwest until the trough line running from Minnesota to Arizona was reached, and then there was a decidedly southwesterly component as the ridge over the Atlantic States was approached. This air flow permitted moist air from the Gulf of Mexico to invade the southern Great Plains, as well as the adjacent Gulf and South Atlantic states. At the same time the central trough enticed polar air masses into the central Plains and the Ohio Valley region. Thus, the scene was set for an air mass battle of great economic importance.

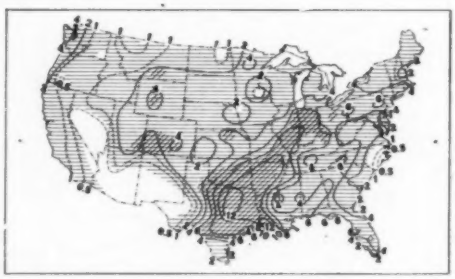
The most interesting storm situation of April occurred during the first week. Among other connected phenomena, it spawned the tornado funnel which threatened for awhile to sweep downtown Dallas, Texas, with disaster on the afternoon of the 2nd and on the same day spread 15 twisters across Oklahoma, dealing death and destruction to a number of communities.

The forerunner of the Southwestern disturbance appeared on the mainland as a front entering the

MONTH OF APRIL 1957



Departure of Average Temperature from Normal in degrees Fahrenheit. USWB chart.



Total Precipitation in inches. USWB chart.

Pacific Coast on 29–30 March in connection with a marked upper-air trough. By noon of 1 April a circulation of growing intensity was stirring up dust clouds ahead and causing blinding snowstorms behind, as it crossed the southern Rockies. The frontal area appeared rather diffuse and innocent on the surface, but aloft the temperature gradient was strong, from the dry polar air to the northwest to the warm tropical air lying over Texas to the southeast. The tropical air, as it glided northwestward, received a double lift from the upsloping terrain and also from the wedge of cold surface air, with the result that the worst spring blizzard in 22 years swept parts of New Mexico and Colorado. As much as 48 inches of new snow fell at high elevations in the Rockies; at Denver a 24-hour fall of 17 inches was near the all-time April record.

The blocking effect of high pressure over Canada was apparent in the future course of the Plains disturbance. From central Texas on the 2nd, the center drifted slowly northeastward for three days, all the while pulling Gulf air northward on its eastern side. Torrential downpours resulted over the Gulf states, the southwestern Appalachians, and the lower Ohio Valley. Many spots received a weekly total in excess of 7 inches from this slow-moving disturbance, and in parts of southern Illinois it was the wettest period since 1950! The rains further retarded farm work, already about two weeks behind last year, but in the long run the effect will be most beneficial in filling much-depleted ground moisture reserves.

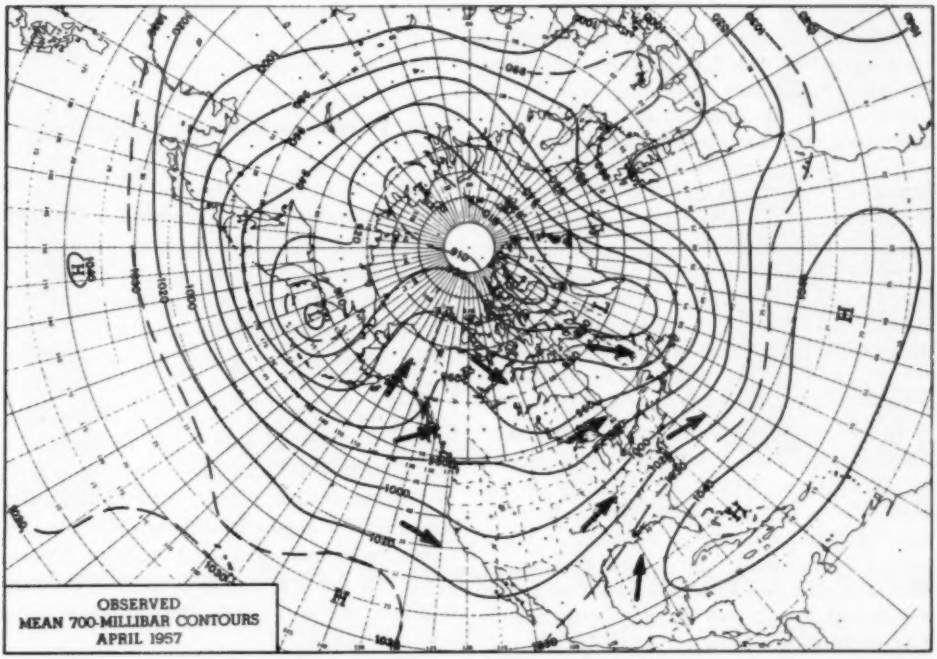
April is always a key month in the agricultural calendar since adequate precipitation available then usually determines the quality of the crops that will be harvested later on, and in some of the fringe areas determines whether any crops at all will grow. April 1957 will be remembered as the turning point in the long struggle with drought in the western reaches of the grain-growing belt of the Great Plains. The current drought has been classified as among the three worst in recorded meteorological history of the western Plains, along with those of 1893–95 and the early 1930s.

As March commenced, rains and snows had already fallen in encouraging quantities over some of the drought areas in Texas and Oklahoma, and during the next 30 days the precipitation spread into the Texas Panhandle and into southwestern Kansas; but large areas in central and west Texas received little, and the entire Rio Grande Valley needed soil moisture badly. Another section in the northern Plains from Nebraska, through the Dakotas, and into northeastern Montana, dry all the winter long, needed more moisture if seeding was to progress and crops germinate properly.

By the end of April rains had come to all of these areas with the single exception of southwestern Texas. In many places the complaints were now of bog-like conditions in fields where a few weeks before dust storms whirled. Some sections of central Texas received more than 12 inches during the month, more than double their entire 1956 catch, and now disaster areas were being decreed for floods rather than for drought!

Heavy rains commenced falling along the Gulf Coast of Texas and in the southern Rio Grande Valley on 14–15 April, and gradually extended their coverage northward and northwestward. On the 19th totals from San Antonio to Fort Worth, through the east-central parts of the state, ranged from one to over two inches. The Waco area was particularly hard hit by cloudbursts on the 19–21st

(*Continued on page 106*)



Statement on Weather Modification

(*Continued from cover 2*)

dry ice. The frequent absence of clear-cut results following the operation of ground-based silver iodide generators is believed to be due to one or more of the following causes: *a*. the failure of the seeding material to reach the supercooled clouds, *b*. the absence of clouds that could be affected by seeding, *c*. the decay of the silver iodide, *d*. the presence of an ample supply of natural ice crystals, *e*. topographical influences which defy quantitative measurement.

5. Cloud seeding acts only to trigger the release of precipitation from existing clouds. The release of substantial amounts of precipitation by either natural or artificial means requires the preexistence of an extensive moisture supply in the form of moist air currents and of active cloud-forming processes. For this reason the meteorological conditions most favorable for the artificial release of precipitation are very much the same as those which usually lead to the natural release of precipitation. This factor plus the extreme natural variability of precipitation makes the evaluation of the effects of seeding difficult and often inconclusive.

6. Evaluations performed by independent agencies have yielded reasonably convincing evidence of increases of precipitation due to the operation of ground-based silver iodide generators only for operations conducted in cold weather in regions where forced lifting of the air over a mountain range is an important factor. No convincing evidence has been presented which indicates that ground-based silver iodide seeding affects the amount or character of the precipitation over flat country. This does not prove that there are no such effects but suggests that if present they are too small to be detected by statistical analyses of data available to this date.

7. In the absence of a truly quantitative theory of precipitation the best present means for obtaining a quantitative estimate of the effect of seeding on precipitation is through the statistical evaluation of randomized cloud seeding experiments. The randomization is necessary to insure valid interpretation of the results and a long series of such experiments may be necessary to detect small effects.

8. Present knowledge of atmospheric processes offers no real basis for the belief that the weather or climate of a large portion of the country can be significantly modified by cloud seeding. It is not intended to rule out the possibility of large-scale modifications of the weather at some future time, but it is believed that, if possible at all, this will require methods that alter the large scale atmospheric circulations, possibly through changes in the radiation balance.

9. All cloud seeding operations should be considered as experiments since the techniques are still under development and there is no sound basis for the quantitative estimation of the results in advance of the operation. As experiments they should be designed primarily to yield optimum scientific results. There is good reason to believe that improved returns from cloud seeding will result from a sound experimental approach and this should be fostered by all concerned.

* * *

The Society has adopted a policy of issuing statements, to be reviewed annually, on a number of weather problems of vital interest to the public. These include the detection, tracking, and prediction of tornadoes and hurricanes; long-range forecasting; fallout of radioactive debris, and other subjects.

The Tornado Research Airplane

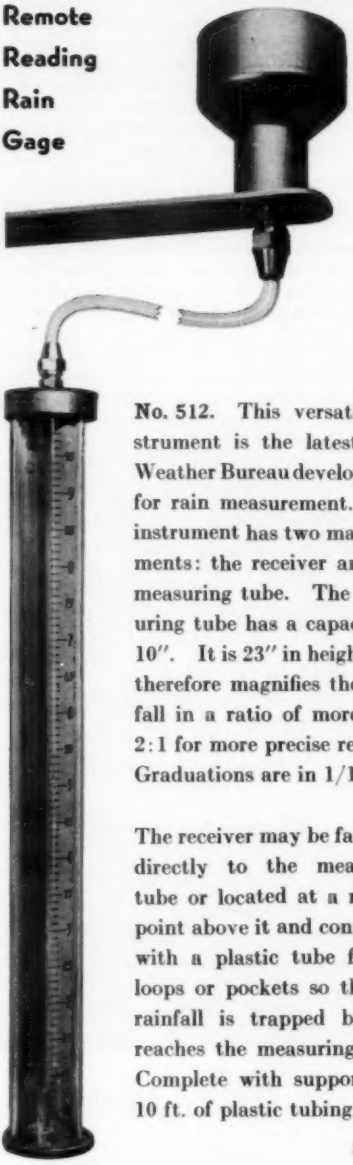
(*Continued from page 84*)

photograph the cloud structure at different elevations, but particularly from as high an elevation as possible. Pictures of active tornadoes many times indicate a clear to broken sky condition upwind from the tornado. This would be an ideal situation for investigation purposes.

In summary, research during the current severe local storms season will be concerned mainly with measuring the vertical structure of the squall line. Even with this limited objective the emphasis will be placed on its formation rather than after activity begins. While the latter is not excluded in planning, it also is not of primary importance in current operations.

Rain Gages

Remote Reading Rain Gage



No. 512. This versatile instrument is the latest U.S. Weather Bureau development for rain measurement. The instrument has two main elements: the receiver and the measuring tube. The measuring tube has a capacity of 10″. It is 23″ in height. It therefore magnifies the rainfall in a ratio of more than 2:1 for more precise reading. Graduations are in 1/10″.

The receiver may be fastened directly to the measuring tube or located at a remote point above it and connected with a plastic tube free of loops or pockets so that no rainfall is trapped but all reaches the measuring tube. Complete with support and 10 ft. of plastic tubing.

$35.00

Farm Rain Gage

No. 510. Direct reading gage fits on any fence post. Made of clear plastic with white graduations. Capacity 6″. Overall length 13″. Complete with bracket for mounting.

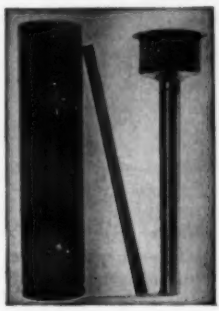
$4.00

Standard Rain and Snow Gage

No. 503. U.S. Weather Bureau type. Funnel is 8″ in diameter. Capacity twenty inches. Brass and copper construction. Stick graduations to 1/100″.

$40.00

Small Rain Gage



No. 508. Green type, Miniature of standard type. Diameter of funnel is three inches. Capacity is 12″. Brass and copper construction. Measuring stick graduated to 1/100″.

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No. 504. Support for No. 503. **$7.50**

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March (*Continued from page 99*)

in the 70's, indicating a good supply of tropical air ahead of the low, while to the rear of the center cold air from Canada was being pulled into the circulation with below-freezing temperatures ranging down to the low 20's.

From southwestern Nebraska the track of the growing storm turned northeastward across Iowa, Minnesota, and Wisconsin. Heavy snow spread over Nebraska, South Dakota, and Minnesota. At Wadena, Minnesota, 19.5 inches fell in a 24-hour period, a record for that locality; and at Sioux City, Iowa, a snow depth of 15 inches was reported, also a March record. To the east of the Plains blizzard, the intense circulation pulled warm air northward as far as Ontario and Quebec, pushing temperatures in the Ohio Valley and Middle Atlantic States to record high date readings on the 13th and 14th.

The main storm center moved very slowly northward, giving the Upper Lakes region its severest pounding of the winter season with 70 mph winds. The further course of the intense disturbance reflected the influence of the blocking high in the Northeast. Near Hudson Bay the center turned eastward, then looped southeastward over central Quebec and passed into the Atlantic near the Gulf of St. Lawrence, rather than pursuing a direct northeastward course to Iceland.

Blizzard No. 2 was much more complicated in its physical structure and movement and proved to be more newsworthy due to the more southerly area affected and the later period of the season. Another front crossed the Pacific coastline on the 21st and was soon stretching from Canada to southern California with two small centers of circulation. The southerly center moved slowly into the existing trough area in north-central Texas where it was centered early on Saturday, 23 March. A very marked closed circulation aloft accompanied the surface low. As the center moved very slowly, it expanded both its size and intensity, and a very tight gradient built up on its northern side as the strongest Plateau high of the spring put in an appearance. Northerly gales, with clockings up to 83 mph, swept the eastern slopes of the Rockies and the western Plains; as temperatures tumbled, rain turned to snow; and the gusty winds swirled the loose snow from the open fields and piled it in monstrous drifts which forced powerful modern streamliners first to a halt and then buried them under a sea of white. Dodge City, Kansas, one of the chief sufferers in the 5-year drought, received 3.06 inches of precipitation during the storm, mostly in the form of snow; unfortunately, most of it was swept from the fields, where it might have been beneficial, into highway ditches and railway cuts. Thirty-four persons died from accidents or from exposure during the storm period. The Kansas Highway Department described the storm as the worst there since 1931.

April (*Continued from page 103*)

as 5.87 inches were recorded. From the 23–29th showers continued over the same area, swelling the storm total at Waco to 13.04 inches. Serious flooding developed along the streams draining central Texas: the Sabine, Trinity, Brazos, Colorado, Guadalupe, and Nueces.

Tropical Gulf air occupied most of Texas throughout the month. The succession of fronts which moved eastward across the state from the Southwestern low pressure area triggered the moisture in a series of prolonged showers. Some of the fronts were preceded by squall lines accompanied by violent hail storms and frequent tornado activity. In all, it was a very turbulent month in Texas.

CROPS—As April drew to a close, the principal areas with insufficient moisture for crop growth were parts of western Texas, most of New Mexico, sections of southeastern Colorado, and a few counties of northeastern Montana and northwestern North Dakota. In all except the last area on the Northern border, May rains made up for the deficiencies of March and April.

East of the Rocky Mountains winter grain areas were favored by unseasonably warm weather and ample moisture in late April and made a rapid advance. Seeding of spring grains and cotton was hampered over the southern Plains and in the Gulf states by too much moisture. Pastures, however, made good progress throughout the country and promised the best forage conditions in several years.

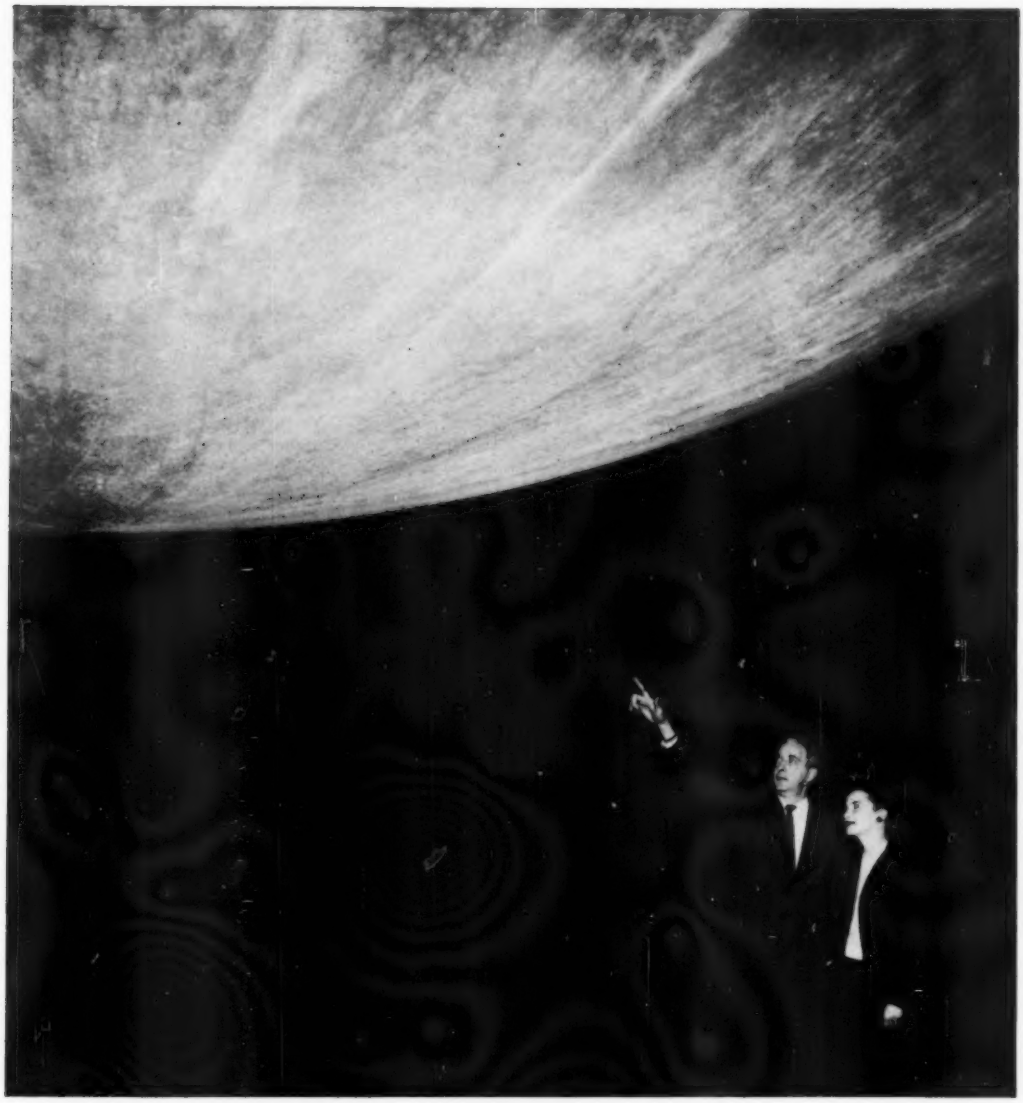
The water supply outlook in the Western Mountain states improved considerably as a result of the April precipitation. Forecasts, issued on 1 May, showed the outlook favorable for ample summer irrigation requirements in the Pacific Northwest, and most of the northern Mountain areas including Colorado and northern Utah. Well below average flows were indicated for most of California and Nevada and for southern portions of New Mexico and Arizona.

HURRICANE GIRLS OF 1957

The following names have been selected for use in 1957 in identifying hurricanes and tropical storms in the Gulf of Mexico, Caribbean Sea, and Atlantic Ocean area:

AUDREY — BERTHA — CARRIE — DEBBIE — ESTHER — FREIDA — GRACIE — HANNAH — INGA — JESSIE — KATHIE — LISA — MARGO — NETTY — ODELLE — PARRY — QUINTA — ROXIE — SANDRA — THEO — UNDINE — VENUS — WENDA — XMAY — YASMIN — ZITA.

Let's hope that we do not meet them all!



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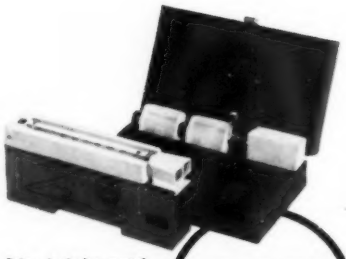

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